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●

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●

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Notice the stuffing box which provides a dry chamber for the operating threads.

●

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Write for full description, prices, or model demonstration.

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National Defense and the Individual

By Willard Chevalier

AT THE outset may I extend to our Canadian friends and neighbors my cordial greetings as a visitor to their Dominion and my warmest thanks as a beneficiary of their always thoughtful hospitality. And to that may I add—as a benevolent non-belligerent—my heartiest congratulations on the job they have done with their Victory Loan. I learn that you have gone over the top with a total of $806,834,600, a premium of $206,834,600 over what you were asked for. And this, I understand, is your third war loan. In only a year and a half, you oversubscribed one loan three times, a second loan twice, and now, on the third call, you top by $100,000,000 your record Victory Loan of 1918.

But that was to be expected. Canada does not do things by halves, especially when she is called to do a job for that great family of nations which we know as the British Empire, and of which she is an honored and respected member.

The people of the Dominions, it appears, are just as determined as those of the embattled isle itself that "there'll always be an England."

Another heartening feature of the Victory Loan is the great number of individual subscribers. I'm told that during the last week the low-denomination bonds ran out of print—so many of your people in the low-wage brackets wanted them.

An address delivered on June 24, 1941, at the All-Section Dinner of the Toronto Convention by Colonel Willard Chevalier, Publisher of *Business Week*, New York City.

This is all of a piece with the resolution of the plain people of Britain. For this time no one can doubt that you are fighting a people's war rather than a ruler's war. In other wars, there have been those who ridiculed the patriotism of the plain people, who tried to sow among them the suspicion that they were being exploited as dupes of the so-called "ruling classes." But this time the plain people of the democracies have left room for no such misgivings. They know it is *their* fight, they have *accepted* it as their fight, and they know that they *must win their fight.* For if they go down to defeat, they surely will lose all that democracy has made possible for them, all that they have won, so slowly and so painfully through centuries of toil and struggle.

Yes, Winston Churchill was right when he called upon Britons so to bear themselves that when their history should finally be written, it might be said of them, "This was their finest hour." And Britons are answering that call as he knew they would, because to the last man, woman, and child, they know better than anyone else in the world that in this hour they are putting to the test all that Britain and British institutions mean to them and to free men everywhere. It *must* be their finest hour.

And that is why my compatriots and I echo the prayer that there'll always be an England. And that is why the vast majority of our people are trying desperately to mobilize our resources to help make that prayer come true.

Hitting Our Stride

I say "the vast majority" because, unhappily, it is true that many of our people have not yet hit their stride in our own defense effort. As a businessman friend of mine put it the other day, so far we have a nice, comfortable, defense program—comfortable for the armed services, for business, for labor, for the politicians, for the nation as a whole. A nice, comfortable one-shift defense program it is.

But such a program will not do. The urgency is too great. We cannot possibly play the part for which we are cast if we pull our punches even a little bit, in a battle into which our antagonists are throwing all they have and all they can steal.

It is about this defense effort of ours—for I must remember not to call it a war effort—that I should like to talk tonight. And I shall talk about it from the viewpoint of a business man, for the outcome of this battle will depend on what industry can do. And that

means, in paramount measure, what the industry of Canada and the United States can do.

If the Axis powers continue to lead in war production, if the New World "arsenal of democracy" fails to supply munitions and equipment in sufficient volume, Hitlerism is bound to prevail and we shall have to face life in a world of his liking and his making.

This is neither the time nor the place to rehearse in detail the facts and figures of the effort we *have made* thus far and the effort we *shall have* to make if the Nazis are not to prevail. But I do want to emphasize that what we *have* done is not a patch on what we still *have to* do.

The other day President Roosevelt declared that Americans would rather die on their feet than live on their knees. So say we all, but if we are going to do that, it is about time for us to get up off our seats and on our feet. At least, that is the plain inference to be drawn from the figures that measure our defense effort—both those that measure what is in the bag and those that measure what is yet to come.

We Talk of "Catching Up"

I say this in no critical spirit. I know that the Nazis had a head start, that we hardly knew what we wanted until a year or so ago, that we have been going through a period of tooling up and of prodigious preparation. I am not criticizing; I am merely trying to draw a common-sense comparison between what has been done and what remains to be done.

When Canada entered this war and when the United States embarked upon its present foreign policy, we each staked our national security on our ability to outarm any possible combination of potential enemies. And, as war is waged, in these times, that means on the ability of our industries to out-produce any possible combination of potential enemies.

Now if that meant merely to out-produce them in the field of peacetime goods and services, the job would be a cakewalk. If it were a matter of producing more radios, automobiles, hats, clothes, or shoes, we'd have them licked from the start. The New World standard of living is impressive evidence of that.

But, unhappily, that is *not* what it means.

The job we've taken on requires that we hang up new world records in the production of guns, tanks, planes, ships, shells, and a

whole lot of other items that are unfamiliar to us. To enter such an armament race we had neither the factories, the skills, nor the experience. We had to build the factories, but there was no time for building. We had to train the men, but there was no time for training. We had to learn how, but there was no time to go to school.

But somehow, we're going to do it. We've got to do it. For we *must* become an effective—yes, an invincible—"arsenal of democracy" if our democracy is not to perish from the earth. And democracy is fighting its battle for survival today—not five years hence, not next year, not even this Fall. But now, today, this minute.

A New Industry—Armament

Putting all this, and a world of things besides, into a very few words, it means that our America—yours and mine—has had to give birth to a new industry—an armament industry. And what an industry! And at what travail to our national life!

Let us try to get a measure of its magnitude. Right now, the United States is spending on national defense about $1,000,000,000 every month. That is a lot of dollars. If a man had had $1,000,000,000 when Our Lord was on the earth and if he had lived until now and spent $1,000 every day since then, he still would have about $290,000,000 of it left. And already we are spending one of those $1,000,000,000's each month.

Look at it another way. We think of the automotive industry of the United States as a rather husky operation. Yet in 1929, its biggest year, the automotive industry did not attain one-half the $12,000,000,000 volume that now is being turned out by our armament industry. And remember that it took the automotive industry more than 20 years to achieve its peak, whereas our modern armament industry is less than two years old.

By the middle of next year, they tell us, this fledgling industry should be pouring its product into American defense and aid to Britain at the rate of about $24,000,000,000 per year.

Yet, they say, this is not enough. The other day Donald M. Nelson of OPM declared that if we are merely to match what the Germans are doing, we shall have to turn out arms and munitions to the tune of $35,000,000,000 per year. And, he said, we must do that quickly—not in 5 years or 2 years from now—but as quickly as we know how!

He bases that estimate upon the fact that last year Germany spent

on armament about $28,000,000,000. That was between 60 and 70 per cent of her national income. It represented something like $350 per capita for its people. For 1940 and 1941 the United Kingdom and the Dominions are spending between $15,000,000,000 and $16,000,000,000 per year. That is about 50 per cent of the national income and nearly $300 per capita for the United Kingdom. For the Dominions it figures 18 per cent and $77 per capita.

Now, with the accessions of natural resources and man-power through her conquests, it is expected that Germany will be able to step up her armament production to $50,000,000,000 per year.

But Great Britain scarcely can better her $15,000,000,000 production and the Dominions just do not command the resources to increase this substantially. So that leaves the United States the job of raising the $35,000,000,000 difference. And that is merely to match the German might.

But whatever the totals may be, it is enough for us to know that we both have on hand about the biggest job we ever tackled as nations—*considering the paramount factor of time.* The volume, of itself, is not staggering. Right now, in the United States, we are plowing something like 15 per cent of our national income into armament. That figures about $77 per capita. It's the need to step this up so far and so fast that puts us on our mettle.

Our Personal Responsibilities

Now this job is not going to get done—and it *must* be done—unless we all are prepared to do our own respective parts. I mean our *personal* parts.

Of course, our governments have the grave responsibility of determining just what they want of industry and of keeping the ring clear for industry to produce. Industry has the responsibility of putting all its resources, facilities, and technical genius—without stint—into meeting the nation's need. Labor has the responsibility of seeing that those resources and facilities are used to the utmost, that the wheels are kept turning without interruption, so that we shall waste none of the precious hours left to us. Every group, every section, every community from the Arctic Ocean to the Rio Grande has its special responsibility in this paramount job.

But this evening I do not intend to talk of *group* responsibilities. Neither is this the time or place to discuss the many diverse technical problems that are involved. We are met here as an international assembly, and I am not competent or qualified to attempt that.

Tonight I would confine what I may have to say to our *personal* responsibilities, to those matters that are the concern of each one of us, that lie on our personal doorsteps, regardless of class, group, or station. Yes, and I may add, regardless of nationality, for in such matters there can be no material difference in outlook or attitude between Canadians and their kinsmen from south of the border.

For when we set out to mobilize all of our resources, we must think of more than raw materials, industrial capacity, and military skill. Our first line of defense is not in our military prowess or the machinery of our factories. It is not in the gold buried at Fort Knox or even in the skill of our industrial workers.

The first line of national defense is wrought of the spiritual and moral fiber of the individual citizen.

The first requirement of national security is not a matter of tanks, guns, planes, ships and the skill to use them; it is one of character, and character is essentially personal. No nation can have a character higher than that of the people who compose it. It is silly to talk of the character of Canada or of the United States apart from the character of the Canadian people and the American people. It is stupid to forget that the British character, standing so steadfast in epic defiance of Churchill's "blood-thirsty guttersnipe," has any existence apart from the character of individual Britons.

So it is a matter of primary concern to this defense effort that we, as individuals, get straight within ourselves, our attitudes toward our respective countries and toward what we call our national institutions. For national defense is a matter of attitude before it is a matter of action; and unless attitudes are sound, action is bound to falter.

From this point, I must ask the indulgence of our Canadian hosts, because I want to offer a few thoughts to my fellow Americans. I want to ask them to check over with me some of the hazards that may lurk in our own minds and in our own hearts. With them, I should like to face frankly just a few of the enemies within ourselves, those enemies that must be whipped by each individual one of us, if we are to succeed as a nation in conquering our alien enemies.

If any Canadian should find anything helpful in all this, no harm will have been done. But it would be presumptious of me to say to him what I may, with perfect propriety, say to my fellow-countrymen. Be it understood, then, that from this point I am speaking of and to my own people.

Public Weakness No. 1—Complacency

The first weak spot in the American citadel of national defense that we should face frankly is complacency. It takes many forms, all of them dangerous. One of these is the notion that we do not need to extend ourselves because we are "biggest"; because we have the "greatest" resources; because we are the "smartest" people. And above all, because we are the "richest" nation.

All of which may be true—or it may not. But even if any part of it were true, it offers no reason for complacency. For any smug appraisal of our strength overlooks a few facts that are far more certain and surely more grimly urgent.

First among these is the fact that national defense is, in itself, a highly specialized industry, one in which we are very inexpert.

Second we should understand that national defense cannot be improvised. No longer is it merely a matter of grabbing the old flintlock from over the mantel and taking one's place in the ranks. Today, national defense requires time and organization—and then more time.

Related to this is the third fact that last time we Americans waged victorious war we had two clear years, at least, in which to prepare. And even then, we had to draw upon our allies for most of our materials and equipment. This time we must prepare our own manpower, and even while we are doing that, we must equip both our allies and ourselves. This is a different kind of a show.

Then, too, we have not yet really sensed how much of our productivity we must divert from meeting our personal pleasures to meeting the national needs. We have yet to learn that you cannot fight a rattlesnake with one hand and toast marshmallows with the other. The time is very close when we shall have to eat our marshmallows plain, and while we are counting our gold, we had better remember that we can't stop a "blitzkrieg" with a billion dollars. We first must build a "blitz" of our own—and that takes time.

And when it comes to that, all the money in the world can't buy yesterday. The only time we have is today and tomorrow—and tomorrow may be eternally too late.

These, I say, are some of the more obvious truths we must lay to our hearts, if we are not to fall victims to the complacency that threatens to bewitch so many of our people.

Taking Things for Granted

But there is another form of complacency even more virulent than this. It may well be fatal because it touches the mainspring of our effort. It involves our attitude toward the very institutions we are girding ourselves to defend.

I mean our pathetic willingness to take quite for granted our country, its institutions and its benefits.

During my generation we have heard an awful lot about our rights, our privileges, and our opportunities. But we have heard precious little about our obligations, our debts, and our responsibilities. Always we have sought to keep our minds on the income side of the account.

Today, it seems to me, one of the chief enemies within ourselves is this tendency to bear down so hard on our personal rights and privileges and to forget so utterly the personal responsibilities that go with them—that are, in fact, the only sure guarantee of their preservation.

But lately we have had a shock. We have seen that the bulwarks of what we so blandly take for granted are not quite so secure as we had assumed. Some of them already have been swept away. Others are tottering.

We have stood aghast as the gallant sons of the European democracies have laid down their lives in desperate efforts to stem the progress of a machine that steadily grinds to pulp all that we have taken so lightly as "inalienable rights." And as we have watched, we have begun to sense—dimly at first, but with increasing vividness—that in other days, other men—among them some Americans, too—must have labored and suffered and died to win those priceless gifts, to safeguard them, and to put them within the reach of us all.

Sergeant York, the Tennessee soldier who achieved distinction in the World War, put it well. He pointed out not long ago that we did not inherit our liberties as a gift. We merely hold them under lease, and we must be prepared to pay for them as we go.

At all events, no decent American, whether he be one by birth or adoption, now can contemplate those liberties, of which he is so vain, without asking himself at what price they have been won. For now, if never before, he must understand that sometime, somewhere, someone paid that price.

And then, if he is but half a man, he must ask himself, "What price am I willing to pay to preserve them?" And if he has the de-

cency and the guts I think he has, his complacency will have dissolved forever.

If he is a business man—in [illegible]k or black—he will know that "business as usual" is out—for the duration. If he is a politician—in or out of office—he will know that "politics as usual"—is out—for the duration. If he is a labor leader—in power or seeking power—he will know that "strikes as usual" are out—for the duration. And if he is any mother's son, or daughter, of [illegible] or she will know that "selfishness as usual" is out—for the duration.

When we are able to do that, we shall have vanquished complacency, one of the most formidable of the enemies within ourselves.

The Ostrich Habit

The second of these enemies within ourselves is a certain reluctance to face facts. We Americans always like to think of ourselves as practical idealists. But, practical as we may be in our personal affairs, we're inclined to be rather fantastic idealists when it comes to international matters.

Now, ideals are very admirable up to a point. But they are in fact no more than fantasies—visions of fine things, if you please—until men have shed "blood and sweat and tears" to convert them into realities. The difference between the visionary and the man of vision lies in just this matter of how he uses his ideals. The visionary worships his, the man of vision works his.

But many of our fellow Americans worship their ideals so ardently that they have come to regard them as being, of themselves, a force for good. And if once they get so far as to put their ideals into words, they seem to delude themselves into believing that they have forged a weapon of great power.

Unhappily, in this realistic and cynical world, no ideal is worth an ounce more than the force its disciples are willing to put behind it. This is not a world of sweetness and reason and light. It is a world of struggle and strife and labor. Pious platitudes may serve the ends of peacetime politics, but they are futile weapons with which to meet an armed and aggressive enemy.

Consider the facts that now give us so profound a concern. They have been there to see ever since 1933 at the latest. During that time the Nazis have turned seven years of national energy into a devastating weapon of conquest. They did it in full view of a watching but listless world. And we have turned the same seven years' energy into—what?

If now we are to do the job we have undertaken, we must first of all write off any lingering hope that we can find national security in national isolation. That issue has been taken out of our hands for good and all. We must face frankly the fact of our involvement in world affairs, whether voluntary or involuntary, whether we like it or not, for better or worse. We must see clearly that in a world dominated by force there can be no security for anyone, however well intentioned, except in superior force. To refuse to face such facts is to let another enemy into our ranks.

We're Too Easy With "Us"

A third enemy within ourselves is a certain lack of self-discipline. This is one of the most bitter fruits of that pre-occupation with individual rights and privileges which has marked this generation of our people. Related to it is the amazing collapse of American respect for leadership—for any worthy leadership.

Among us has arisen a cynicism that puts to scorn any spirit of personal sacrifice, that laughs off the natural instinct of decent men to assume cheerfully the obligations and responsibilities that go with their estate as free men.

This cynicism has been nourished in many quarters and from a variety of motives. One of the most obvious of its sources is the flood of books, plays, and propaganda that has engulfed us since the first World War, devoted to an orgy of disillusion and bitterness. "Debunking" has been the order of the day. We have debunked love of country, worship of God, loyalty to the day's work and respect for ethical standards. We have "debunked," in fact, just about everything that earlier generations of Americans were brought up to respect. And in place of all that, we have been invited to worship self-indulgence, self-justification, and self-aggrandizement as the only gods worth the devotion of a free American people.

Apt illustration of what I am talking about is the subversive agitator, who climbs upon a public platform, wraps himself in the American flag, claims the protection of the liberties for which it stands, and then perverts the priceless privilege of free speech to undermine and destroy the very institutions that guarantee it to him. Likewise, the authors, playwrights, politicians, and propagandists who have smeared American institutions *ad lib* for two decades. It is this sort of thing that has taught so many Americans to take for granted all that they have and are.

A major casualty of this exaltation of personal privilege over per-

sonal obligation has been the loyalty we call patriotism. And how sorely we shall need just that loyalty, if we are to surmount this greatest crisis in our history!

Respect for Our Leaders Imperative

Another of its casualties is a respect for leadership or, to put it another way, a capacity for self-discipline. We have been taught to be so scornful of our leaders. Politicians make political capital by deriding the failures of business leadership. Business men fight back by deriding the failures of political leadership. All hands are so busy tearing down respect for some kind of leadership that we have all but destroyed American respect for decent, competent, responsible leadership in any sphere.

But men must have something to respect, so we have fallen hard for a cult of mediocrity worship. Its high-priests are the articulate mediocrities—those masters of the art of dressing up half-truths and sheer nonsense so seductively as to delude great masses of the people. Of course, the chief ingredient of such pap is the sure-fire appeal to egotism and self-interest. It appeals to so many because it exalts the rights and privileges of the individual and belittles any and all claims upon him. It teaches us to dismiss contemptuously the notion that the individual should pay for his rights and privileges in the form of any personal loyalty and sacrifice—except, of course to the high-priests themselves and their stooge organizations.

The natural result of such trading on human frailty is that any leadership that calls frankly for the facing of facts and the paying of prices is condemned out of hand in favor of the more delightful doctrine of take all today and let tomorrow go hang.

Unhappily such appeals too often strike a responsive chord with people who have been accustomed to take all their blessings for granted—as their right. They've been told so often that "one man's as good as another, and a damned sight better" that they've come to believe it. So they have little respect for any authority or leadership that dares to tell them anything that is unpleasant, unpalatable, or realistic. We have been taught to revile and distrust any leaders except those who invite us into the primrose paths of easy living at the expense of someone else.

Because of this wholesale tearing down of past leadership through the "debunking" process and of present responsible and realistic leadership through the appeal to sheer selfishness, we have pathetically few popular leaders in American life today, aside from promis-

sory politicians, professional athletes, moving-picture stars, and comic-strip characters.

But if democracy is to succeed in this practical and realistic world, it needs competent leadership—and needs it terribly. For only through intelligent, realistic, and self-sacrificing effort can democracy survive the crisis that now confronts it.

This means that we must regain some of our old-time respect for, those who have the character and the competence to lead us honestly, wisely, and resolutely. If we, as Americans, are to measure up to the challenge of this hour we must—each one of us—develop once again a sense of responsibility to something beyond our personal rights, our personal privileges and our personal gratifications.

We must rewrite into our vocabularies the words "loyalty"—"devotion"—"respect." We must re-learn the elementary lesson of life—that everything worth having commands its price and unless we are willing to pay that price, we cannot hope to retain it.

And what is even more difficult for some of us to swallow, we must recognize that this applies even to our personal talents and powers. I always wince when I hear the expression "self-made man." In the free democracies of the world, there cannot be a "self-made man." For every man's success is due to in some measure to the very liberties, benefits, and opportunities that have enabled him to develop his talents and to turn his capacities to his personal advantage.

And this means that we should be willing to dedicate even our personal talents to the common good rather than try to apply them exclusively to personal benefit. And the greater our personal capacities, the greater the obligations that rest upon us.

If American democracy is to succeed in meeting this challenge, it will be because our people, as individuals, have not forgotten these truths. It will be because we, as individuals, still cherish the moral qualities that impel decent men to respond instinctively to the call of those institutions from which they have derived all their opportunities, their privileges and their personal powers.

We stand today on the threshold of a great test. The decision may be reached on the battle-fields of the land, the sea, or the air. But wherever the final verdict may eventually be read, we may be sure that its terms already are being written in the hearts and minds of the Canadian and American peoples as individuals.

For character is the essential—the indispensable safeguard of national security; and character is essentially personal.

Chlorination Equipment Available for Emergency Use

By Harry A. Faber

WHILE it is impossible to foresee when an emergency will arise, the measures to handle it can be prepared well in advance. The purpose of this paper is to provide specific information regarding equipment which is available for, or which may be adapted to, emergency chlorination of water supplies.

Normal treatment and distribution of a safe water supply is subject to interruption by acts of nature or of man. It has been pointed out (1) that, because a public water supply is essential both for domestic needs and for fire fighting, water department authorities have a definite responsibility to provide equipment which will insure the minimum interruption of water service. During the past few years, experience has demonstrated not only the necessity of continual vigilance under normal conditions of operation but the necessity of being prepared to meet abnormal conditions. Chlorination is recognized as a necessary factor of safety in the normal treatment of water supplies. It is equally essential that provision be made to insure the delivery of water disinfected by chlorination in time of emergency.

The experience of those who already have gained familiarity with this problem provides the best basis for development of any new program. Descriptions of those procedures demonstrated to be effective warrant careful study. Papers by Arnold (2) and by Devendorf (3) report a variety of experiences with emergency chlorination measures. These were adopted to treat public water supplies contaminated under conditions of normal operation. Papers by Gledhill and McCanlis (4) and by MacKenzie (5) describe the development of successful disinfection procedures for combating

A paper presented on June 23, 1941, at the Toronto Convention by Harry A. Faber, Research Chemist, The Chlorine Institute, Inc., New York City.

pollution resulting from fracture of water mains by high explosive bombs. Other pertinent reports appear frequently in the Abstract Section of this JOURNAL.

In order to perfect a clear plan of action, it is necessary to determine the requirements of each supply and each situation. Experience shows this can best be accomplished by providing three essentials: the man, the material, and the machine.

The Man

Prompt and effective emergency chlorination can be no better than the personnel which has been made responsible for the job. General rules of procedure cannot be laid down for all municipalities, or all supplies, or all emergencies. Rather, the plan developed must be based on the conditions which obtain in each locality.

Authority should immediately be delegated to a competent member of every water supply organization to survey the local situation. His survey should include a study of each potential weakness in the normal operation of water chlorination. This is no time to place dependence upon inadequate or obsolete chlorinating equipment. This is no time to lack duplicate chlorinating units or spare parts necessary to uninterrupted operation. This is no time to lack the protection of secondary chlorination at points where re-contamination is possible: at storage reservoirs, floating reservoirs, and distribution reservoirs.

Under abnormal conditions a water department may find itself called upon to supply much more than the normal quantity of water, either through wastage from broken mains, or in order that fire fighting can be carried on effectively. Chlorinating equipment must be ample in capacity to disinfect increased volumes of water required by these causes. Under emergency conditions, too, special portable or mobile units may be required either to disinfect contaminated sections of a distribution system or to treat a separate emergency supply. The survey should consider each of these contingencies because, while abnormal, they are certainly potential occurrences.

When this survey is completed it will present the strength and weakness of a local situation: where chlorination is necessary, where it is provided, and where additional or emergency chlorination may be required. This survey, however, represents only the recognition of the situation. The second step, therefore, is to provide the indicated total protection to the best of one's ability. In the case

of a small water system, only minor provisions may be required, while in the case of an extensive system many weaknesses may require correction. There will probably be no better time than the present to secure any funds necessary for new equipment.

Finally, a detailed plan of procedure should be worked out and put in written form. Each chlorinating unit and each point of chlorine application is a point of potential disinfection failure. The detailed plan should indicate, as simply as possible, exactly what procedure is to be followed in the event of failure. If a duplicate unit is to be substituted, if an emergency unit is to be provided, if the chlorine dose is to be increased elsewhere, that instruction should be clearly stated.

The individual who has studied the entire situation and who has drawn up the detailed plan of procedure would then be the logical man to whom full authority should be delegated. Only when complete responsibility is given to one individual will prompt and decisive action be forthcoming. This is necessary, also, because the chlorination authority must co-operate with those responsible for other phases of emergency procedure. The program of emergency chlorination must be integrated with the entire program of plant operation, distribution system repair, and emergency sources of supply.

Such a precautionary problem is applicable, irrespective of the size or number of employees of the water system. Only when one individual is given responsibility and when adequate precautionary measures have been provided can criticism be forestalled, excessive emergency expenses prevented, and the well-meaning but often dangerous efforts of incompetent individuals or organizations discouraged.

The Material

Liquid Chlorine

The availability of liquid chlorine for disinfection of water supplies has already been indicated (6) in the JOURNAL. In the event of emergency, it is not probable that large additional amounts of chlorine will be required; instead, different points of application will be utilized. The proposed plan of emergency procedure should, however, include a survey and listing of emergency sources of supply. Nearby sewage treatment plants, swimming pools, laundries, or industrial plants should be contacted, and the potential emergency supply of liquid chlorine available from all such sources should be determined.

Hypochlorites

Many small water treatment plants regularly use calcium hypochlorite for disinfection. This chlorine compound provides an excellent source of emergency chlorine for even the largest plants. Modern calcium hypochlorite contains 70 per cent available chlorine, and is generally supplied in drums containing 100 lb. and in cans containing 5 lb. These hypochlorites are stable over a long period of time if stored in a cool, dry place. Hypochlorite solutions are, however, corrosive to common materials, so suitable equipment must be available to feed them.

Two such hypochlorites are available in the United States: "HTH," manufactured by the Mathieson Alkali Company, and "Perchloron," manufactured by the Pennsylvania Salt Mfg. Co. In Canada there is one such hypochlorite: "Maxoclor," manufactured by the Canadian Industries, Ltd. Each producer has available a booklet which provides useful information on the preparation and feeding of hypochlorite solutions.

This material may also be available through local distributors who supply laundries, industrial users, swimming pools, and other consumers. Each of these sources should be surveyed as a potential source of supply when facilities are provided to feed hypochlorites.

Other Chlorine Compounds

So-called "bleaching powder," or "chloride of lime," is available from local distributors in many localities. This material generally contains about 35 per cent available chlorine when fresh, but is not stable over a long period of time. Local sources should be investigated, however, if emergency equipment for feeding hypochlorite solutions is provided. Limited amounts of this material may also be found in drug, grocery, hardware, or poultry supply stores in one-pound cans.

Sodium hypochlorite solution, usually containing about 15 per cent available chlorine, is obtainable through local jobbers in some localities. This solution may be purchased in 5-gallon carboys. Frequently small producers of household bleaching solution use this material, or make it from caustic soda and liquid chlorine, and market it under a wide variety of trade names in grocery stores. As sold, the solution is usually very dilute, ranging from 3 to 5 per cent available chlorine. It might be used to provide very small amounts of chlorine for emergency needs.

The Machine

Chlorinators

Standard chlorinating apparatus are not unusually heavy pieces of equipment. The units regularly employed in water purification may, in emergency, be transported readily to the various points of need. Chlorinator manufacturers are best able to designate the type of equipment most suitable for particular uses. There are two manufacturers of chlorinators: Wallace and Tiernan Co., Newark, N. J., and Everson Manufacturing Co., Chicago, Ill. They offer standard chlorinators suitable for various types of installations and for a wide range of dosage requirements.

Wallace and Tiernan Co. is experienced in the design and construction of mobile chlorinating units, using standard vacuum chlorinators, and has assisted in the design of other such units which were assembled and mounted by the customers. This company offers a stock model portable chlorinator, suitable for either direct or solution feed, which is especially applicable for sterilization of mains. The outfit is mounted in two compact cabinets, and is adaptable to a variety of uses. In addition, a new mobile trailer unit has been designed, completely equipped with a chlorinator, two cylinders of chlorine, and a self-powered pump.

Pumps for Feeding Hypochlorite Solution

Small pumps, which operate on a variety of principles, are available to feed hypochlorite solutions for disinfection. They are constructed of resistant material and have proved thoroughly satisfactory in service. Again in this case, the manufacturers will be most competent in designating the type of equipment best suited to each purpose. The units are suitable for continuous, emergency, or special chlorinating purposes and may be either manually controlled, operate automatically at a fixed dose, or provide a dose directly proportional to water flow.

The two types of this equipment best known in the water treatment field are those manufactured by Proportioneers, Inc., and by Wallace and Tiernan Co.

Proportioneers, Inc., Providence, R. I., offers a wide variety of such pumps under the name of "Chlor-O-Feeders." These range in capacity from 85 to 240 g.p.d. maximum delivery. They operate by electric power, belt drive, water power, compressed air, or by

power from a gasoline engine. In addition, duplex, triplex, and combinations up to five units can be provided, with a capacity of 180 g.p.d. for each pump. The "Pur-O-Pumper" unit, consisting of pump, filter, and hypochlorite feeder, is powered with a gasoline engine.

Wallace and Tiernan Co. offers several models of a hypochlorite pump, feeding a maximum of 60 g.p.d. These "Hypochlorinators" operate by electric power, belt drive, water power, or by power from a gasoline engine. Duplex pumping units are also provided in this equipment. Self-powered units consisting of pump and hypochlorinator or of pump, filter, and hypochlorinator, are also available.

Other manufacturers offering a more limited variety of hypochlorite pumping units are:

Everson Manufacturing Co., Chicago, Ill. One model, electric power, 24 g.p.d. maximum capacity.

Omega Machine Co., Kansas City, Mo. One model, electric or water power, 400 g.p.d. maximum capacity.

Milton Roy Pumps, Philadelphia, Pa. Simplex model, electric power, 432 g.p.d. maximum capacity; duplex model 864 g.p.d. maximum capacity.

Wilson Chemical Feeders, Inc., Buffalo, N. Y. Five models, electric or water power, standard capacity 96 g.p.d., and others.

Hypochlorite Feeders Other Than Pumps

Omega Machine Co., Kansas City, Mo., offers a "Precision" feeder to deliver hypochlorite solution against zero back-pressure or to a pump suction. This device consists of a storage tank from which the discharge of solution is controlled by electric motor, spring-operated clock drive, water motor, or by any reciprocating or rotating shaft. Maximum capacity is given as 192 g.p.d.

Phipps and Bird, Inc., Richmond, Va. offers a hypochlorite solution feeder, operating by either gravity or electric power, to deliver against back-pressures of zero or up to 60 lb. Maximum capacity is given as 45 g.p.d.

C. W. Sirch, Los Angeles, Calif., offers a "Paradox" feeder for hypochlorite solution, which operates by pressure differential between two points in the water main. Discharge rate is over a large range.

Home-Made Hypochlorite Feeders

For temporary application of hypochlorite solution under emergency conditions, a variety of other feeding devices can be pressed into service. They should, however, be considered for temporary use only, since it is not possible to provide accurate or dependable dosing except through the use of a machine specifically designed for that purpose.

In emergency, any dry feed machine may be used to feed dry hypochlorites into a solution box, and the solution may be discharged by gravity or pumped to the required point of application. Only the 70-per cent calcium hypochlorite can be fed in such manner. Even this material, however, is slightly hygroscopic and corrosive upon exposure to the atmosphere, so that its dry feed application must be limited to short periods of use only when no other equipment can be provided.

Several types of gravity or pump suction feeders can be made to serve during an emergency, when no standard solution feed device can be provided. Their accuracy and dependability, however, can never compare with equipment designed for the purpose. Hypochlorite solutions are corrosive to common metals, and parts used must be of suitably resistant materials such as glass, wood, rubber hose, hard rubber, etc.

Hypochlorite solutions can be applied against pressure by using an injector. The pressure differential between the injector feed and discharge should preferably be 5 to 1 and must be at least 3 to 1 in order to obtain satisfactory operation.

Residual Chlorine Testing Equipment

Proper control of chlorine dosage will usually be dependent upon the maintenance of a desired chlorine residual. Testing outfits are available both for the residual range covered in ordinary disinfection and for that which may be necessary in emergency chlorination.

For chlorine residuals of 0.1 p.p.m. to 1.0 p.p.m., outfits are offered by: La Motte Chemical Products Co., Baltimore, Md.; Proportioneers, Inc.; Rascher and Betzold, Inc., Chicago, Ill.; and W. A. Taylor and Co., Inc., Baltimore, Md.

For chlorine residuals of 0.1 p.p.m. to 2.0 p.p.m. outfits are offered

by: Hellige, Inc., Long Island City, N. Y.; and by Wallace and Tiernan, Inc.

For chlorine residuals of 0.2 p.p.m. to 8.0 p.p.m., an outfit is offered by W. A. Taylor and Co., Inc.

For higher chlorine residuals, outfits ordinarily used in testing bleaching or sterilizing solutions are offered by: Diversey Corp., Chicago, Ill. (100 p.p.m. maximum); Hellige, Inc. (250 p.p.m. maximum); La Motte Chemical Products Co. (100 p.p.m. maximum); Rascher and Betzold Inc. (220 p.p.m. maximum); and W. A. Taylor and Co., Inc. (250 p.p.m. maximum).

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Experiences With Emergency Chlorination Equipment

By G. E. Arnold

AN EMERGENCY may be defined as any condition, arising outside of what may be classed as normal operations, which calls for impromptu or special consideration and treatment. Conditions which make sterilization necessary may be created in a number of ways, and while some of these do not constitute emergencies in the literal sense of the word, the method of dealing with them is similar to that which would be utilized in actual emergencies even though there may be a forewarning of the event that will permit some preparation for it. The construction of a new pipe line or new reservoir, or other water works structure, the placing in service of new construction of this type, or again the placing in active service of a structure which has been out of use for some time, all may be considered emergency conditions. From time to time biological growths occur in water systems which require special treatment; changes in operating procedure; shutdowns for the overhauling of equipment; power failures; breakdown of equipment; and such occurrences might all be considered emergencies.

The San Francisco Water Department's handling of such emergencies depends entirely upon the conditions confronted and the amount of treatment required. For the sterilization of new street mains of short lengths or small sizes, chloride of lime is introduced either by placing a small portion of the chemical in each joint of pipe as it is laid or by introducing an amount of it into the water used to fill the line for test. For pumping small quantities of chemical into lines under pressure, a small hand-operated force pump is used. This pump consists of a double cylinder taking suction from a tank or

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barrel and forcing the fluid into the line under pressure. The equipment is sometimes used for sterilizing piping in buildings or on consumers' premises. Panel-type dry-feed chlorinating equipment is also available to feed chlorine gas into a line at pressures up to 25 lb. In a few instances, chlorine cylinders have been directly connected to lines, the flow of gas being controlled by an auxiliary tank valve. This procedure, however, is not generally recommended.

Portable Chlorinator

A number of years ago, the Department built a portable chlorinating machine for general and emergency use. This machine consists

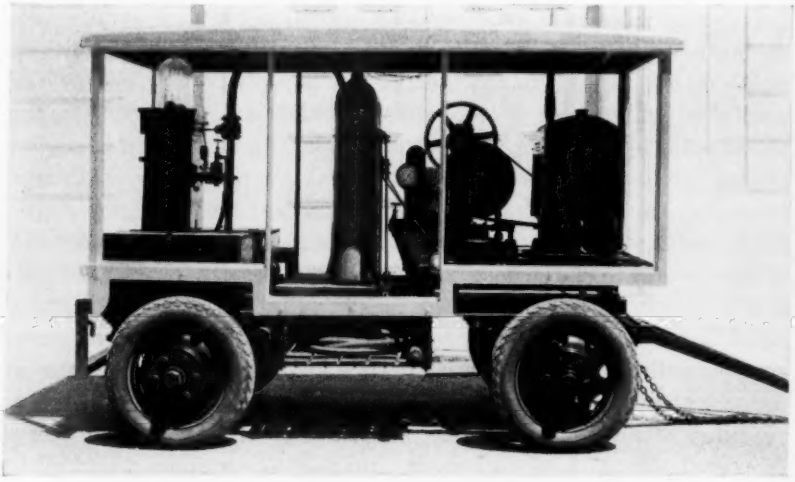

FIG. 1. Portable Chlorinating Unit, all side panels removed; note discharge hose coiled up in carrying box below frame of trailer

of a 300-pound capacity vacuum chlorinator mounted on a four-wheel trailer together with a gasoline-engine-driven water pump and two 150-pound chlorine cylinders. The chlorinating machine is mounted at the rear of the trailer, the gas engine and pump at the front of the trailer, space being provided between the two for chlorine cylinders (Fig. 1). The chlorinating unit is of the high-pressure type, manually operated and equipped with various sizes of injector throats and manometer tubes to feed chlorine dosages varying from 10 to 300 lb. per day.

The water supply for the chlorinator is provided by a triplex, three-cylinder, reciprocating pump which will deliver water up to

300 lb. discharge pressure. Piping between the pump and chlorinator is equipped with pressure reducing valves and bypasses to meet varying operating conditions. The proper water pressure for the injector can be obtained by increasing or decreasing the speed of the gasoline engine, which is connected to the pump by means of multiple V-belts operating on pulleys. Increasing the speed of the pump increases both the quantity of water delivered and the pressure. The unit is also equipped with a pressure water intake, bypassing the pump, so the chlorinator may be operated without the pump if a high pressure water supply is available. The pump intake is a standard

FIG. 2. Portable Chlorinating Unit Ready for Service; taking suction from fire hydrant and discharging chlorine solution through service outlet, from which meter is removed.

2-inch pipe equipped with accessories to take all sizes of standard pipe and fire hose so that suction may be taken from a fire hydrant or any convenient water outlet (Fig. 2). Suction may also be taken from an open conduit, ditch, or reservoir. The discharge from the chlorinator is a 200-foot, steel wrapped, rubber hose, equipped with standard silver solution tube and also with standard pipe fittings so the chlorine may be discharged into any convenient outlet or into a fire hydrant.

The chlorine cylinders are held upright on a platform between the pump and the chlorinator. Clamps hold the cylinders in place so

that the unit may be moved. Flexible tubing connects to a pipe manifold which carries the gas to the chlorinator. The entire unit is housed in a steel body welded to the trailer frame. All side and end panels of the housing are removable for accessibility. With the panels in place, the unit may be locked up and left operating on the street. There is a trap door in the roof of the unit for removing the bell jar from the chlorinator. Two special wire clamps keep the bell jar in place while the unit is being moved. The entire unit is light in weight and may be towed behind any small truck, and the trailer is equipped with a hand brake for parking.

General Use

The equipment has been used many times. During some repair work on one of the regular chlorinating stations, for instance, it was necessary to shut down the station for several days. During this time regular chlorinating activities were carried on with the portable chlorinating equipment.

Some years ago, a new source of water supply was introduced to the San Francisco system and for several months before the completion of a regular chlorinating station, chlorination of the supply was done solely with the portable equipment. In this case a small electric motor was mounted in the trailer to operate the pump instead of the gasoline engine; and in both instances chlorine supply was taken from ton containers placed on temporary platforms adjacent to the equipment.

When pipe lines of large size or considerable length are laid, they are sterilized with the equipment before being placed in operation. In these cases, two convenient taps are made on the pipe line, one for pump suction, the other for chlorine discharge.

About two years' ago, one of the larger customers of the San Francisco system installed a new pipe line of its own, which, upon testing, showed a marked degree of contamination, probably from the jute used in packing the joints of the cast-iron pipe. This line was chlorinated several times with the portable equipment before the contamination disappeared.

In several instances, too, chlorination of new distributing reservoirs has been carried out with the equipment. As the reservoir was filled, a heavy dose of chlorine was applied to the incoming water, the equipment being mounted on the reservoir embankment and the solution discharging directly into the incoming water. In one or two

instances old open reservoirs have become contaminated and effective chlorination of the water in the reservoir has been accomplished with this equipment.

Some years ago, when a slime growth developed in a portion of the distribution piping of a neighboring community, the entire distribution system affected was chlorinated. This work was done largely at night, suction for the machine being taken from one fire hydrant, the chlorine solution being discharged back into the system through a hydrant at the next corner. During the operation, the equipment was moved several times from one point to another, very little time being consumed in making these moves.

Use in Emergencies

There have been several actual emergencies for which the equipment has been used in the past several years. Several years ago, for instance, a cross-connection at a water front industrial plant in San Francisco resulted in pollution of the water system. In this case, a large pump was being used to pump salt water from the bay for fire protection and for washing around the plant. The pump, having a vertical discharge, was primed, through a cross-connection with the public water supply, directly into the discharge line of the pump. The operator primed the pump with fresh water and started the pump, failing to close the valve on the fresh water line. Salt water was pumped back into the street main for some time before it was discovered. The Water Department flushed out the mains in the neighborhood through fire hydrants and afterward sterilized the mains by chlorination with the portable chlorinating unit.

A sewer empties into the bay at a point near the industrial plant and the bay water there is contaminated. Bacteriological samples obtained from the street mains after flushing showed some evidence of contamination, but after chlorinating the mains, all samples showed no contamination. Fortunately no cases of sickness developed from the occurrence.

In another instance, a well used for irrigating the grounds at a public park was cross-connected to the public water system through some toilet connections. Polluted water was pumped into the distribution system from this well. As soon as the pollution was discovered the system was thoroughly flushed and chlorinated with the portable equipment. By closing certain operating valves it was possible to chlorinate the entire section affected from one place.

These incidents occurred despite the regulations regarding cross-connections in San Francisco. Some occurred prior to the cross-connection elimination program.

In another case a large passenger steamship docked in San Francisco with a badly polluted water supply on board. This water had been picked up at another port. While the ship was docked in San Francisco the water piping on board was flushed, refilled, and chlorinated, using the portable equipment. Subsequent tests showed the water on board ship to be free from pollution.

Application in Pollution at Treasure Island

A recent case was that of the pollution of the water piping at the Golden Gate International Exposition in August, 1940. The Exposition was held on an island in San Francisco Bay. The piping on the island consisted of two separate systems, a high pressure fire system and a low pressure domestic system, both, ordinarily, being kept filled with water from the San Francisco Water Department mains. The low pressure system was supplied through pressure reducing valves from the high pressure system. There was also connected to the high pressure system a salt water manifold to which could be connected a fire boat operated by the San Francisco Fire Department. This manifold was located on a pier at the east end of the island. The fire boat taking suction from the bay could pump salt water into the high pressure system. On Saturday, August 24, a fire occurred in the California Building on the Fair grounds. Some time later the fire boat went into operation pumping bay water into the high pressure fire system. For some reason the valves between the two systems were not shut and the salt water got into the domestic system.

When the exposition officials called on the Water Department for assistance, the portable chlorinating equipment was dispatched to the island to disinfect the water system. Sterilization of the low pressure or domestic system was accomplished first by connecting the portable equipment to a fire hydrant and to an irrigation outlet. A chlorine dosage of approximately 50 p.p.m. was applied to the water used in flushing the pipe system. Operating valves were manipulated to force this highly chlorinated water into all portions of the piping system, care being taken to see that each outlet was flushed until chlorine residual was detected. Following this, the high pressure system was disinfected, using two fire hydrants on this system. This heavily chlorinated water was allowed to stand in the piping for

several hours and was then flushed out. Bacteriological samples taken before the disinfection from a number of points in the Fair grounds showed evidence of contamination but all samples taken after the sterilizing operations showed the piping to be free from contamination. It is believed that the chlorine solution reached every foot of piping on the Fair grounds, both in the domestic and high pressure systems.

On the day of the fire there were 69,000 people on the island. The next day there were 108,000 on the island. Had it not been for this effective work in chlorinating the piping system on the island it would not have been possible to open the Exposition the following day.

The San Francisco Water Department has been called on a number of times by other cities or water districts for assistance in similar emergencies. The portable equipment has been dispatched in such cases accompanied by an operator from the Department.

The chlorinator, representing an expense of about $2,500, is considered one of the most valuable pieces of equipment in the Department's Service. It is the author's opinion that all cities should be equipped with some such piece of apparatus, since in the event of military action which might disrupt normal operations, a major fire or earthquake, or any other unexpected disaster, it would be an invaluable aid.

The Pollution and Emergency Disinfection of Rochester's Water Supply

By Earl Devendorf

FROM about 4 P.M. on December 11, 1940, until 8 A.M. the following morning about five million gallons of raw Genesee River water were accidentally pumped into the public water supply system of the City of Rochester, N. Y., with the result that about 75 per cent of the city's 500-mile distribution system became seriously polluted. This condition arose from the inadvertent opening of a valve on one of a number of cross-connections between the municipally owned water system and the municipally owned high pressure fire system—connections which had been reported eliminated by the previous authorities of the water department.

The contingency that resulted was one of the most serious to confront the New York State Department of Health in recent years. A description of its occurrence and of the action taken to protect the residents of the city is particularly interesting information in this period of national emergency.

The City of Rochester, with a population of about 325,000, has two potable public water supply systems, one, municipally owned, serves about 80 per cent of the population, and the other, owned by the Rochester and Lake Ontario Water Co., serves the remaining 20 per cent, as well as a population residing in areas outside of and adjacent to the city.

The municipally owned water supply, known as the Hemlock supply, is obtained by gravity through three conduits from Hemlock and Canadice Lakes. These lakes are located some 35 mi. south of the city and the water is chlorinated before its delivery through Rush reservoir and the Cobbs Hill and Highland Park distributing reservoirs.

A paper presented on June 26, 1941, at the Toronto Convention by Earl Devendorf, Assistant Director, Division of Sanitation, State Department of Health, Albany, N. Y.

The Rochester and Lake Ontario Water Co. obtains its supply, by pumping, from Lake Ontario. The water is filtered and chlorinated before delivery. The company supply has no connection with the municipally owned Holly high pressure fire system and was not affected by the recent pollution of the Hemlock supply.

Holly Fire System

In addition to these potable water supplies, there is a separate municipally owned high pressure fire fighting system, the Holly system, which was installed in 1873. This system consists of about 25 mi. of mains supplying hydrants and automatic sprinkler equipment in the congested mercantile and industrial districts of the city. There is still some industrial use of water from the Holly system. Normally, a pressure of some 95 lb. per sq.in. is maintained by the operation of either or both of two 500-g.p.m. pumps which draw water from a small suction well located at the Holly pumping station. This well is supplied only with water from the Hemlock potable supply. In addition there are four 2,100-g.p.m. fire pumps at the pumping station, used at times of fire to raise the pressure on the Holly system to about 125 lb. per sq.in. These fire pumps take suction from a large suction well, at the Holly station, which may be supplied either by river water or, through a 12-inch main, with water from the Hemlock potable supply that discharges into the suction well above the flow line. Under normal conditions the fire pumps are supplied from the Hemlock potable supply but in case of large fires, the valve controlling the river water supply may be opened to permit river water to enter the suction well.

A study of the city water department's records, dating back to the 1870's, when the Holly fire fighting system was originally constructed, reveals that there were 15 valved connections made between the Holly and Hemlock mains. Since 1926 the existence of cross-connections between potable and polluted water supplies has been prohibited by the State Sanitary Code. In 1928, the city manager of Rochester ordered the elimination of all of the remaining cross-connections known to exist at that time between the two systems. The removal of these cross-connections was reported to have been carried out. Record maps of the city water department, however, indicate that the valves on these connections had been sealed rather than removed, and that, in at least one instance, the valve had been sealed merely by filling the gate box with broken stone.

Since the occurrence of the pollution of the drinking water supply of the city last December, the present Commissioner of Public Works, William H. Roberts, has announced the removal of all cross-connections between these systems.

Occurrence of Pollution

On December 11, following a reported leak in a valve located on State St. near Commercial St., a repair crew of the water department was assigned to make repairs. It was found necessary to excavate to reach the valve and, on completion of the repairs, the workman having found the valve closed, opened it without notifying or checking with the water supply officials. The workman acted, apparently, in the belief that the valve was on the potable Hemlock water supply system, when actually it was one of the old cross-connections between the Holly and Hemlock systems.

Immediately after the valve was opened, the automatic alarm in the pumping station sounded, the gages showing a reduction of pressure which was much greater than normal.

At about 3:30 P.M. that day it also became necessary to increase the rate of pumping at the Holly fire supply pumping station in an endeavor to maintain normal pressure. The smaller pumps were used at first and, when these proved inadequate, the larger ones were put in operation. For the first hour the pumps were supplied solely with the Hemlock supply, but when it became apparent that the capacity of the main furnishing the Hemlock supply was inadequate to provide the amount of water required for the fire pumps, the valve permitting river water to enter the suction well was opened and the valve on the Hemlock supply main closed. As a result, the highly turbid Genesee river water was pumped into the fire supply system and, through the opened valve on the cross-connection, into the Hemlock water supply distribution system.

Since there was no fire to account for the increased demand and since a check of the larger industries failed to reveal any large usage of the Holly supply, it was at first believed that there was a break in the Holly system. This possibility was reported to Water Department headquarters, which assigned a crew to search for the leak. The search continued until some time after midnight with no result; and it was not until the following morning, December 12, when the workman who had repaired the valve on the previous day, reported its opening. Thereupon the valve was immediately closed.

From records of the Water Department and from the rating curves of the fire pumps, it was determined that the volume of river water pumped into the Hemlock water distribution system during the intervening period was approximately 5 mil.gal. The pumping of this large volume of raw river water resulted in widespread pollution of the domestic Hemlock distribution system, particularly so since the river water was pumped throughout the night, when consumption of water in the city was at a minimum. The spread of pollution is corroborated by the results of the chemical analyses

TABLE 1

Results of Chemical Analyses on December 12

DETERMINATIONS	LOCATION OF SAMPLING POINTS					
	Sample 1 Terminal Bldg.	Sample 2—123 Monroe Ave.	Sample 3—Ward St. & St. Paul St.	Sample 4—880 St. Paul St.	Sample 5—890 Monroe Ave.	Sample 6—975 S. Clinton Ave.
Time of Test—	10:30 A.M.	2:00 P.M.	2:15 P.M.	2:30 P.M.	1:45 P.M.	1:30 P.M.
Color, *p.p.m.*	5	0	0	0	0	0
Turbidity, *p.p.m.*	120	5	5	5	Trace	5
Ammonia, free, *p.p.m.*	0.004	0.020	0.014	0.012	0.020	0.010
Ammonia, alb., *p.p.m.*	0.15	0.082	0.078	0.070	0.078	0.088
Nitrites, *p.p.m.*	0.004	0.010	0.008	0.006	0.010	0.007
Nitrates, *p.p.m.*	0.050	0.14	0.14	0.20	0.14	0.14
Oxygen Consumption, *p.p.m.*	4.8	2.3	2.0	2.2	2.4	2.0
Chlorides, *p.p.m.*	26.4	2.6	2.8	4.2	2.6	3.0
Hardness, total, *p.p.m.*	138	68	72	72	68	76
Alkalinity, *p.p.m.*	74	50	50	51	49	49
pH	7.6	7.5	7.6	7.5	7.6	7.6
Iron, *p.p.m.*	3.7	0.3	0.25	0.5	0.17	0.2
Esch. coli, *M.P.N.*	2400 or>	<2.2	8.8	38	2.2	<2.2

on samples collected on December 12, immediately following the discovery of the occurrence (Table 1 and Fig. 1).

Sample 1, it should be noted was collected at 10:30 A.M. and the remaining samples, not until that afternoon when flushing operations undoubtedly had resulted in removing the major amount of river water in the distribution system. Sample 1 shows high turbidity and greatly increased figures for oxygen consumed, chlorides, hardness, alkalinity and iron content, compared to those normally present in the Hemlock supply. Likewise, the bacterial pollution was

extremely high in Sample 1 and remained so in Samples 3 and 4. Samples 2, 5, and 6 presumably represent water collected from points on the distribution system beyond the effect of the river water pollution.

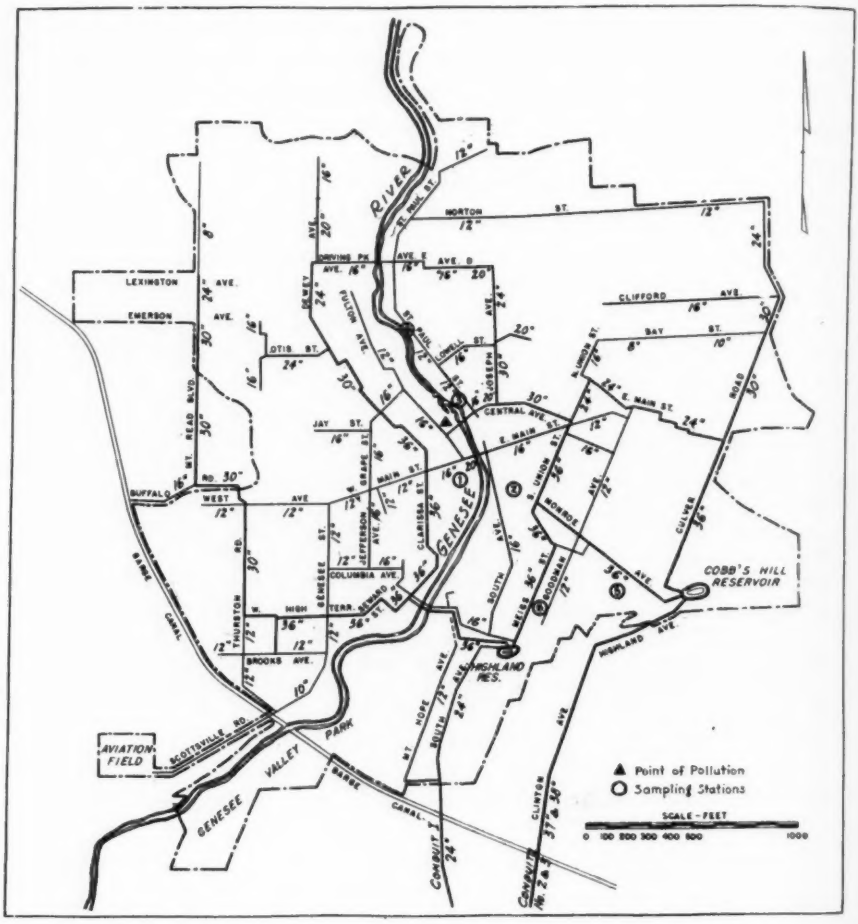

FIG. 1. Location of Sampling Points for Analyses of Table 1

Although complaints of roily water in the downtown section of Rochester had been received in the evening of December 11, apparently no importance was attached to these complaints. Late in the evening, chemists in the laboratory of the Rochester Gas and Elec-

tric Company ran a hardness test because of the high turbidity of the water and found it to have a hardness of 125 p.p.m. as against its normal 70 p.p.m. and the Genesee River hardness of approximately 140 p.p.m. The marked increase in hardness together with the turbidity was interpreted by the chemists to signify that river water had entered the Hemlock system, and this information was reported to the city authorities, but it was not until 8 o'clock the next morning, December 12, when the water works employee reported the opening of a valve, however, that the cause of the difficulty was discovered.

The water works authorities then began to flush the system, but it was not until after 9 A.M. that the City Health Officer, Dr. Arthur M. Johnson, became aware that something was amiss. The large number of telephone inquiries and complaints from citizens prompted him to make immediate inquiry of the water works office. When he found out what had happened, he at once conferred with the other city officials to plan control measures and notified the State Department of Health.

Remedial Measures

As soon as the situation became known, the City Health Officer immediately initiated steps to warn the citizens of the seriousness of the matter and advised them by radio, newspaper and telephone to boil all water before drinking. Notices were telephoned to hospitals, schools, hotels, restaurants, department stores, factories, pasteurizing and soft drink establishments. The Rochester Department of Commerce placed 250 large placards at downtown bus, street car, and subway loading platforms and employed six sound trucks to cruise in the residential areas to warn persons who had not received the radio notice. Guests who had been registered in hotels were advised by letter of the pollution of the drinking water supply and were urged to take inoculations against typhoid fever. The City Health Officer organized typhoid immunization clinics in the Rochester Health Bureau and in the out-patient departments of hospitals. Additional clinics were organized in East Rochester and the adjacent town of Greece.

Arrangements were immediately made for daily laboratory examinations of samples of water from some 50 sampling stations established along the entire distribution system for the purpose of determining the extent of the pollution of the city mains and to de-

termine when such pollution had been removed to the extent that the water could be used safely without boiling.

In addition to flushing hydrants throughout the central and northern sections of the city to remove as much as possible of the river water pollution, the water department arranged for the installation of emergency chlorination equipment at each of the two distributing reservoirs, to treat the water flowing through the distribution system.

TABLE 2

Rates of Chlorination at Distribution Reservoirs

DATE	TIME	VOLUME OF WATER TREATED	RATE OF CHLORINE APPLICATION	CHLORINE DOSAGE	
				Average	Maximum
		mil. gal.	*lb. per day*	*p.p.m.*	*p.p.m.*
Highland					
Dec. 12–13	3 P.M. to 7 A.M.	7.23	40	0.67	2.0
Dec. 13–14	7 A.M. to 7 A.M.	14.5	151	1.25	3.1
Dec. 14–15	7 A.M. to 7 A.M.	11.45	177	1.85	4.0
Dec. 15–16	7 A.M. to 7 A.M.	8.7	205	2.84	5.0
Dec. 16–17	7 A.M. to 7 A.M.	11.6	250	2.6	5.0
Dec. 17–18	7 A.M. to 7 A.M.	11.8	177	1.8	2.3
Dec. 18	7 A.M. to 5 P.M.	6.0	42	0.84	0.86
Cobbs Hill					
Dec. 12–13	5 P.M. to 7 A.M.	4.9	20	0.49	1.2
Dec. 13–14	7 A.M. to 7 A.M.	14.5	139	1.1	3.0
Dec. 14–15	7 A.M. to 7 A.M.	11.45	211	2.2	4.3
Dec. 15–16	7 A.M. to 7 A.M.	8.7	215	2.95	4.1
Dec. 16–17	7 A.M. to 7 A.M.	11.6	212	2.2	4.8
Dec. 17–18	7 A.M. to 7 A.M.	11.8	149	1.5	2.3
Dec. 18	7 A.M. to 5 P.M.	6.0	42	0.84	0.86

Following a conference of local and state health officials on the evening of December 12, immediate steps were taken to obtain additional equipment in an endeavor to increase the amount of chlorine applied to the water flowing from the distributing reservoirs. During the night, additional chlorine equipment was obtained from adjacent municipalities and from manufacturers in Buffalo, but it was apparent, after the second day, that the chlorine residual of tap samples was increasing very little and was not reaching all portions of the distribution system.

Table 2 shows the amount of chlorine applied at the distribution reservoirs from the first day, December 12, to December 18, when emergency chlorination at the distribution reservoirs was discontinued. Although efforts were made immediately to raise the rate

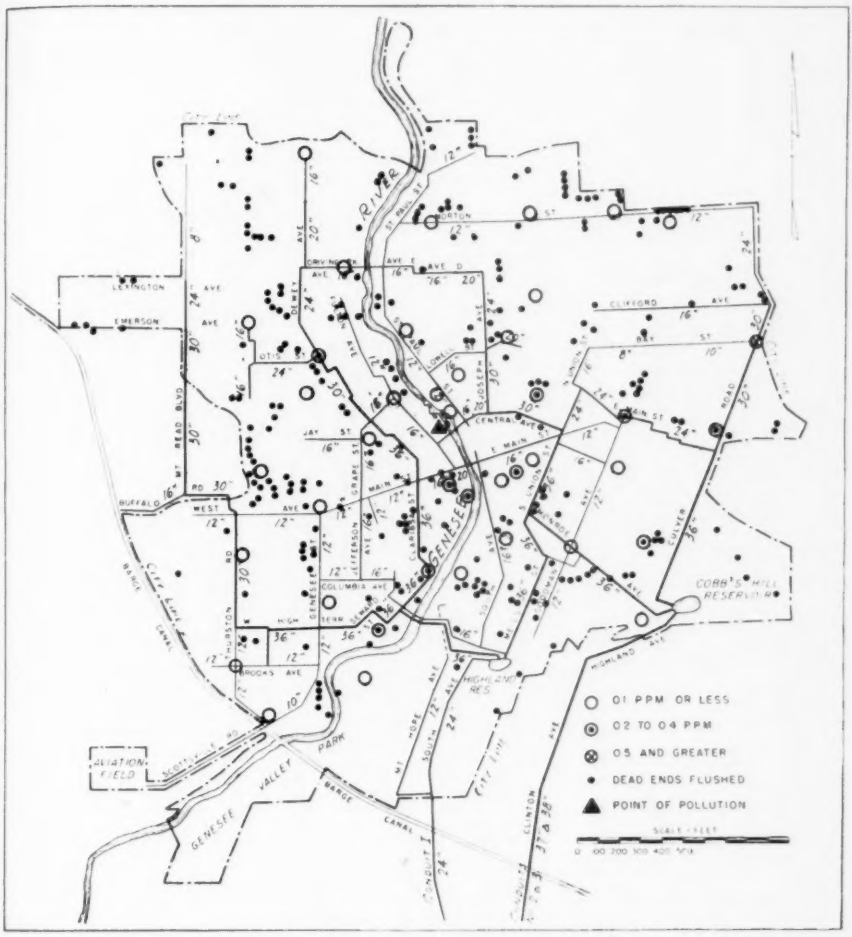

FIG. 2. Results of Residual Chlorine Tests of December 15

of chlorine application to 200 lb. per day at each reservoir, it took three days before this rate of application was obtained, due to difficulties in securing additional chlorine equipment, and maintaining adequate operating water pressures, and to the necessity of installing electric pumping equipment.

Figures 2, 3, and 4 show the results of tests for residual chlorine on December 15, 16, and 17 respectively. The results of the December 15 tests indicated that residual chlorine was not reaching the distribution system at the points desired and for the most part

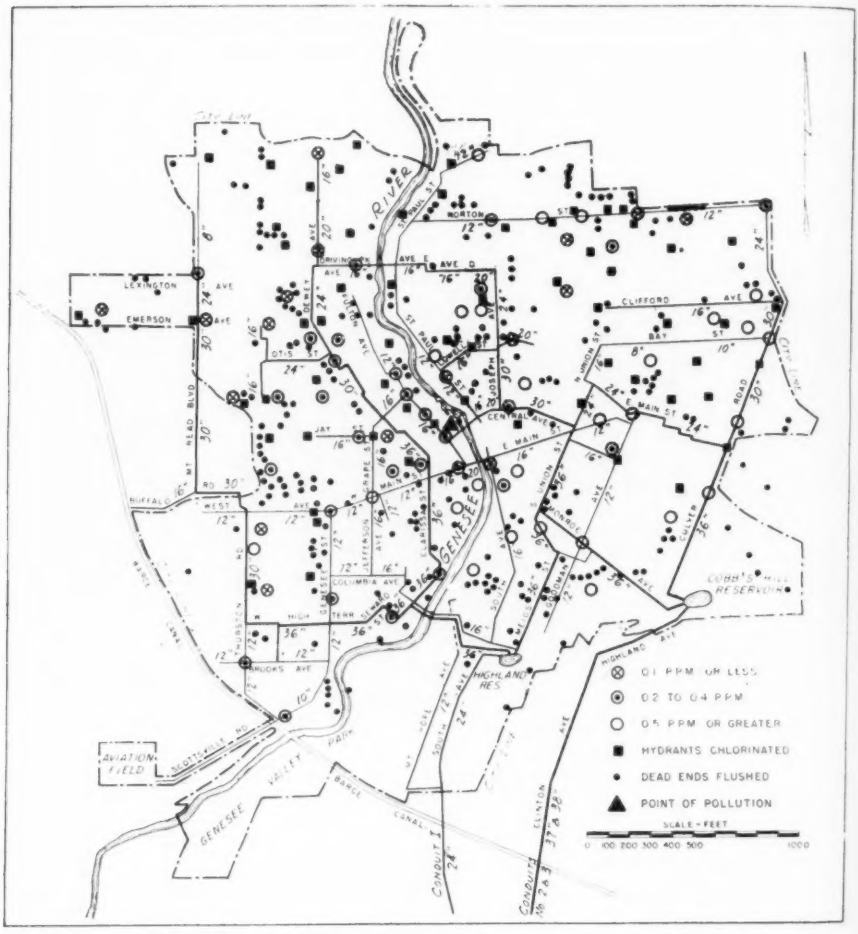

FIG. 3. Results of Residual Chlorine Tests of December 16

residuals were less than 0.1 p.p.m. Many tests in the northern part of the city showed only a trace or no chlorine residual at all. This was particularly discouraging, especially in view of the 48 hr. of continuous labor involved in the work.

With the situation rapidly becoming acute and public feeling aroused, the author and the District Engineer of the State Health Department, George W. Moore, called a conference of the city administration on Sunday morning, December 15. At that time ar-

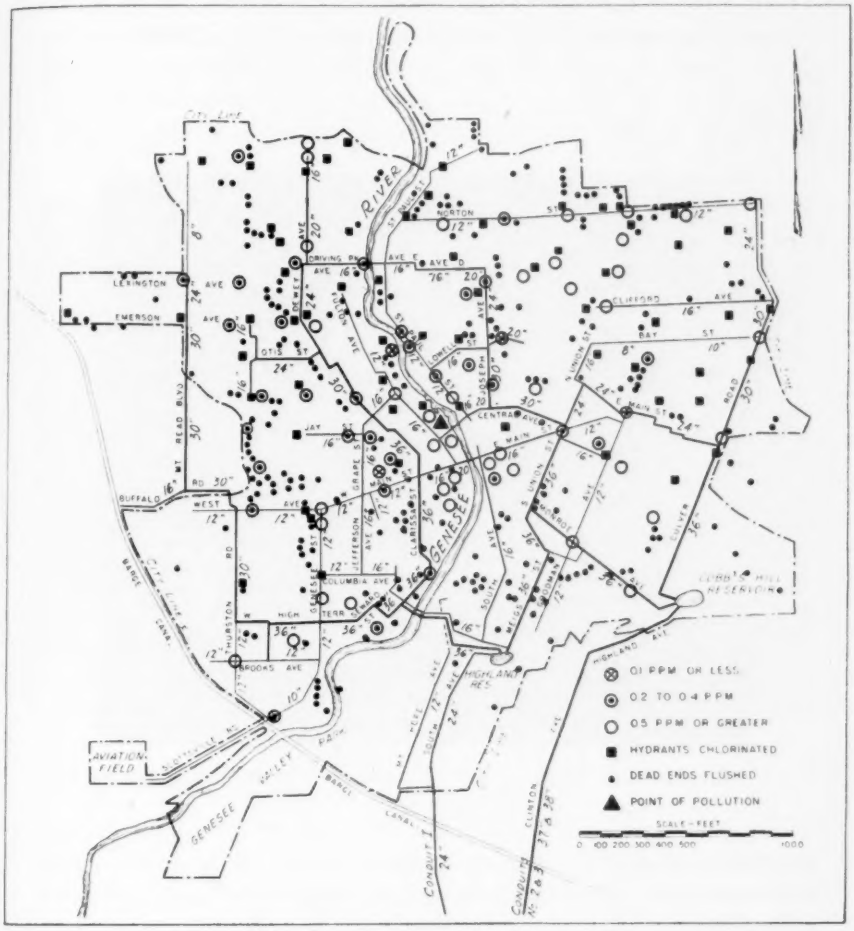

FIG. 4. Results of Residual Chlorine Tests of December 17

rangements were made to secure a ton of HTH, which with the assistance of the personnel and equipment of the Department of Public Works, using street flushers and pumpers, was to be pumped into the distribution system through hydrants. Routes were mapped

out covering the whole northern end of the city and extending a short distance in the southern section, where laboratory examinations indicated that the water supply had been polluted.

Use of Street Flushers and Fire Trucks

Fortunately the Department of Public Works had available modern street flushers and two fire pumpers which could be used to inject the hypochlorite solution into the system. The street flushers (2,500 gal. capacity each) were equipped with pumps which facili-

FIG. 5. Street Flusher; showing method of filling and of mixing hypochlorite solution

tated recirculation and mixing of the solution. A 5-pound dose of HTH to about a foot of water was placed in each flusher tank and recirculated for about 5 min. The flusher was then filled with water from the hydrants and the pumper hooked up, taking suction from the flusher and discharging the hypochlorite solution into the hydrant against city pressure. By this method, at each pumping 2,500 gal. of a solution containing 165 p.p.m. available chlorine were pumped into the distribution system. A hydrant on the main under treatment, about 400 ft. from the point of application, was

opened to induce a flow of about 250 g.p.m. in the main at the point where chlorine solution was being introduced. This resulted in a rate of application of chlorine of about 5 p.p.m. A large number of emergency field kits for making ortho-tolidine tests were provided for the workmen. Immediately upon obtaining a chlorine residual, the hydrant was closed and a hydrant further from the point of pumping, opened until a sample there also indicated a chlorine residual.

This equipment and the available organization made it possible to accomplish sterilization of the large mileage of water mains in a

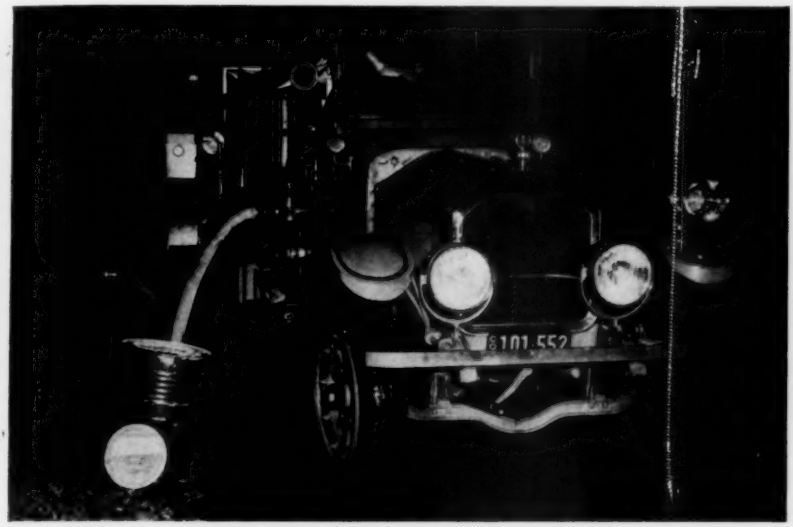

FIG. 6. Fire Pumper; showing pumping of hypochlorite solution from flusher into distribution system through hydrant

fraction of the time that would have been required had chlorination of the distribution system been carried out only by the introduction of chlorine into the water as it left the distributing reservoirs. So far as is known, this method of chlorination of a large distribution system has never, heretofore, been employed. It proved most successful and efficient.

Figure 5 indicates the general type of flusher used and the method of filling the flusher and mixing the hypochlorite solution, and Fig. 6 demonstrates the method of pumping the solution into the fire hydrants.

Figure 3, as previously pointed out, represents the results of tests for residual chlorine throughout the distribution system as made on December 16, following the first night's pumping of hypochlorite solution into the hydrants. These results compared with the results of the previous day's findings show a marked increase in residual

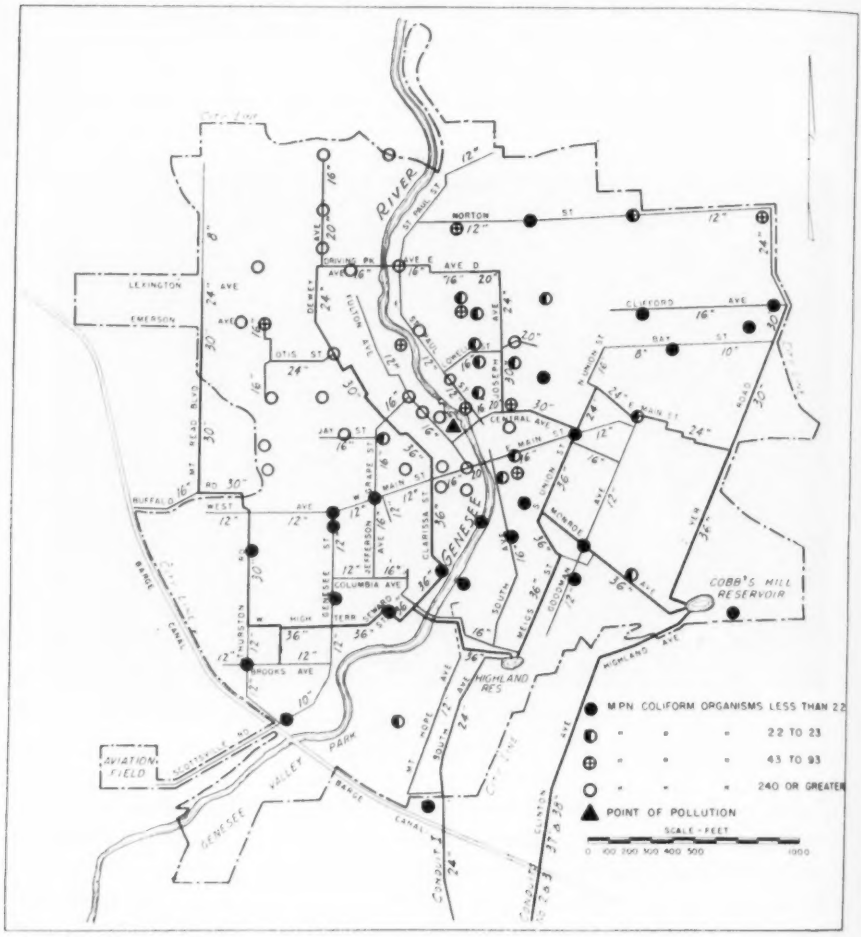

FIG. 7. Results of Bacteriological Tests of December 12

chlorine throughout the distribution system, but still a lack of adequate residuals, particularly in the extreme northern and northeastern sections of the city. Accordingly, it was decided to repeat the hypochlorite pumping operations.

Figure 4, again, demonstrates the results of residual chlorine tests made on December 17. These results show a marked increase in the chlorine residuals throughout all parts of the distribution system. Throughout the day, some 168 hydrants on the dead end were thoroughly flushed, until a satisfactory residual was obtained.

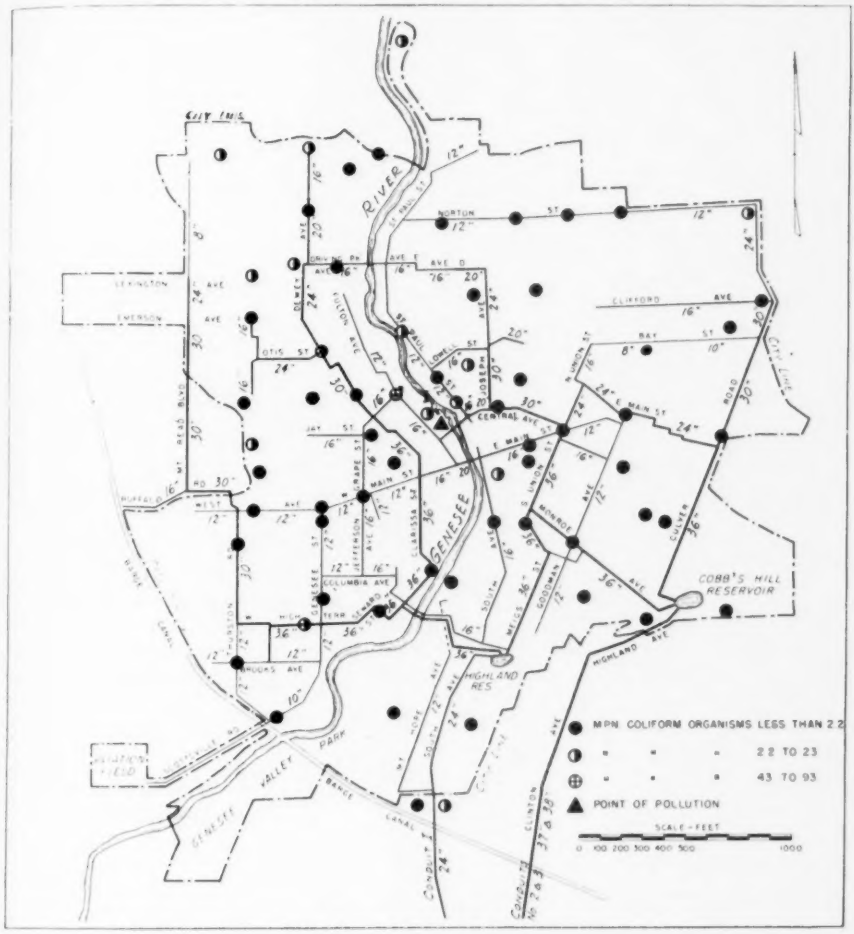

FIG. 8. Results of Bacteriological Tests of December 13

Figures 7 through 14 show the results of bacteriological examination of samples collected from the established sampling stations throughout the city distribution system. Figure 7, showing the results of bacterial examination of samples collected on December 12,

immediately following the discovery of the situation, indicates the widespread distribution of the pollution in the central and northern parts of the city. Of the total 85 samples examined, 57 confirmed for *Esch. coli*, and of these, 30 showed *Esch. coli* of 240 or greater.

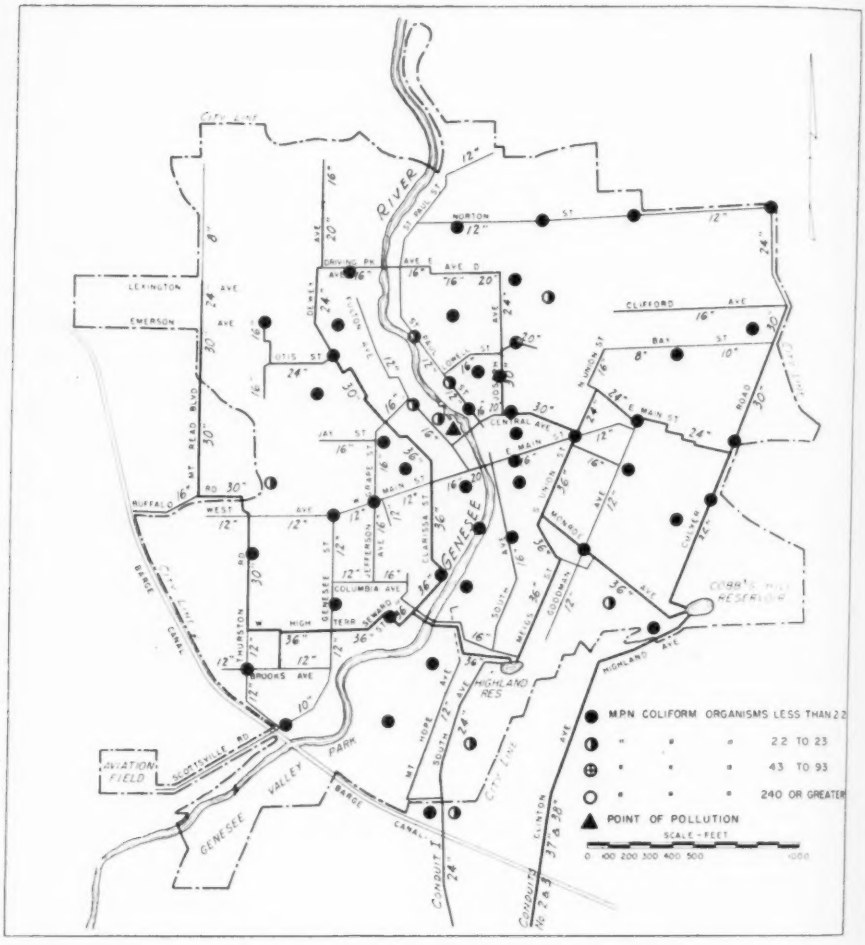

FIG. 9. Results of Bacteriological Tests of December 14

As would be expected these confirming samples were collected from points in the central and northern part of the distribution system, indicating that the pollution was carried mostly to this part of the system and that little reached the southern part.

Figure 8, showing the results of bacterial sampling throughout the distribution system on December 13, following extensive flushing operations carried out by the water department employees, reveals a material reduction in the amount of pollution. Of the

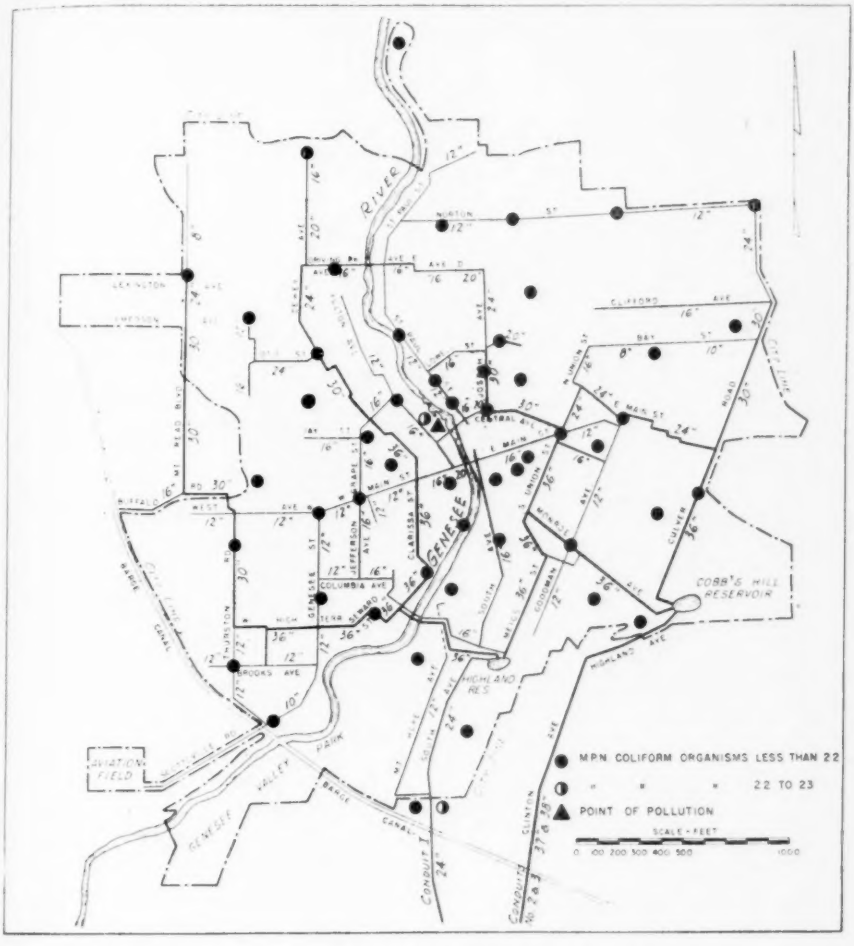

FIG. 10. Results of Bacteriological Tests of December 15

total 77 samples examined, only 16 confirmed for *Esch. coli*, and of these 15 showed an index of 2.2 to 23, and only one an index of 62.

The remaining figures, 9 through 14, show corresponding reductions in the pollution following the continued flushing and pumping of hypochlorite solution into the distribution system.

Table 3 and Figure 15 give the results of bacterial examination of all samples collected from December 12 through 20.

On the evening of December 17, at a meeting of the city and state health officials, it was agreed, on the basis of the evidence of the

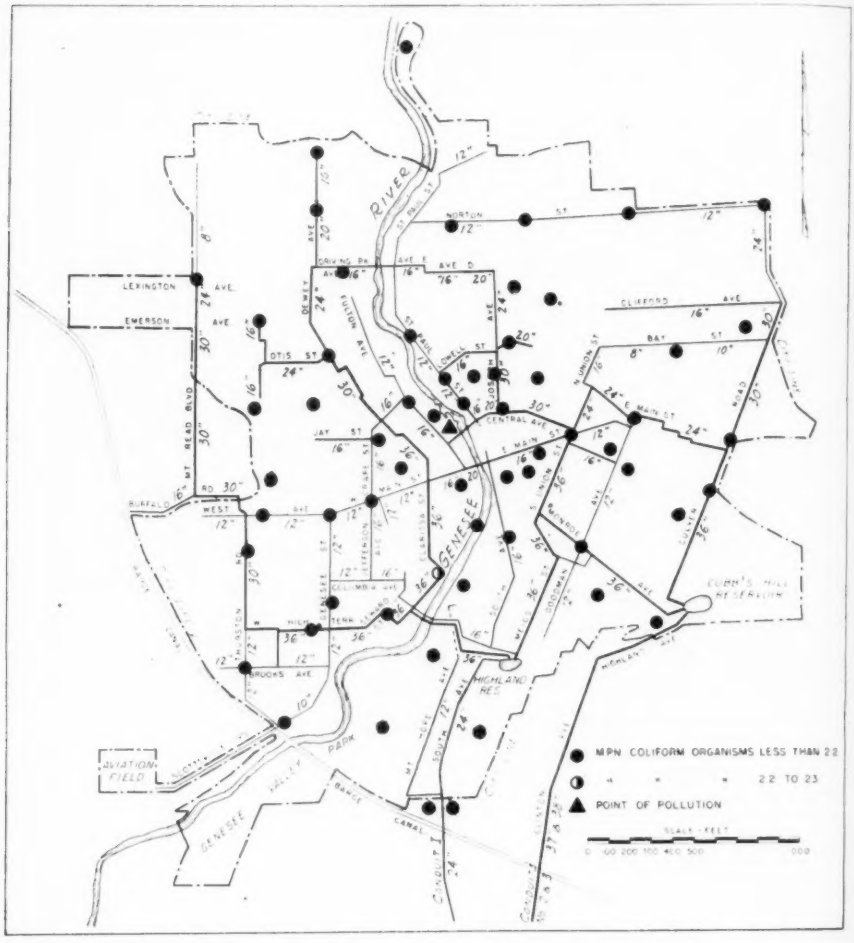

FIG. 11. Results of Bacteriological Tests of December 16

laboratory tests and the ortho-tolidine results on samples collected from the distribution system, that the system had been effectively chlorinated and that the water supply was again safe. Accordingly the city health officer announced to the public that boiling the city water was no longer necessary.

Information assembled co-operatively by Dr. Johnson and Dr. Paul A. Lembcke, District Health Officer of the State Department of Health, based on a house to house survey of representative homes made by public health nurses, indicates that 3,400 inhabitants lo-

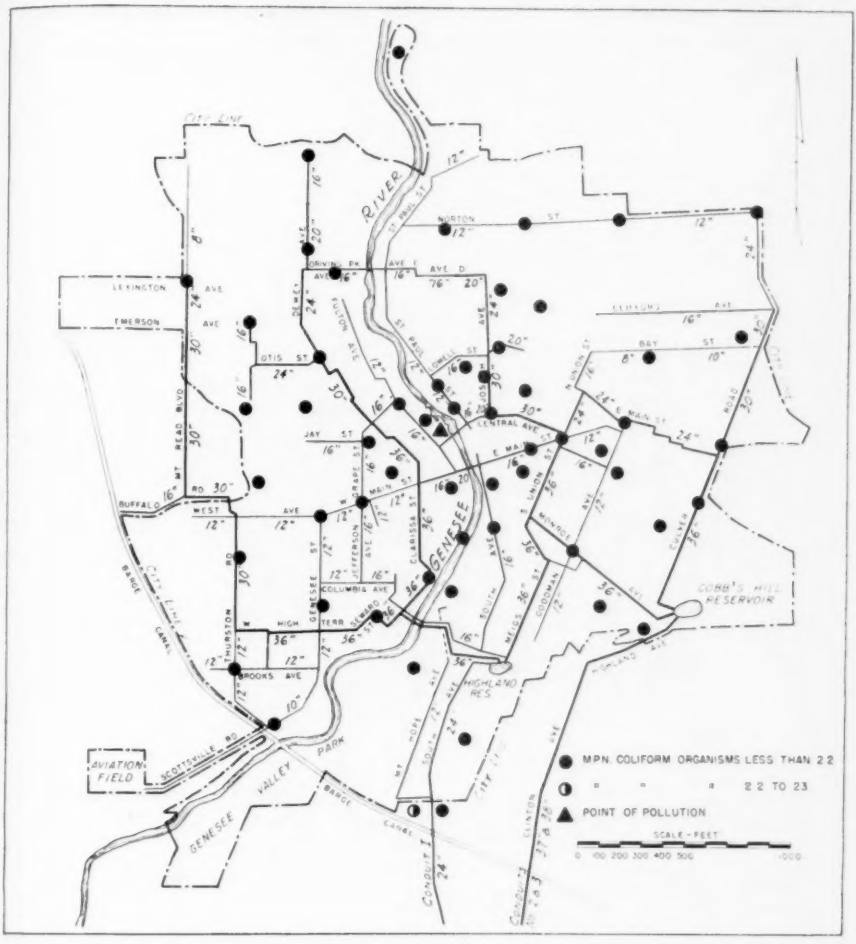

FIG. 12. Results of Bacteriological Tests of December 17

cated in Monroe county, outside of the City of Rochester, and 30,000 city residents became ill following the pollution of the public water supply.

From the District Health Officer it was learned that only six definite cases of typhoid fever were recognized and that one of these was

probably of secondary origin. None died and none became chronic carriers. Each of the patients resided or was regularly employed in the area of Rochester where bacteriological examinations showed the water to be polluted and gave a history of drinking Hemlock water without boiling on December 11 or 12. Individual suits for damages

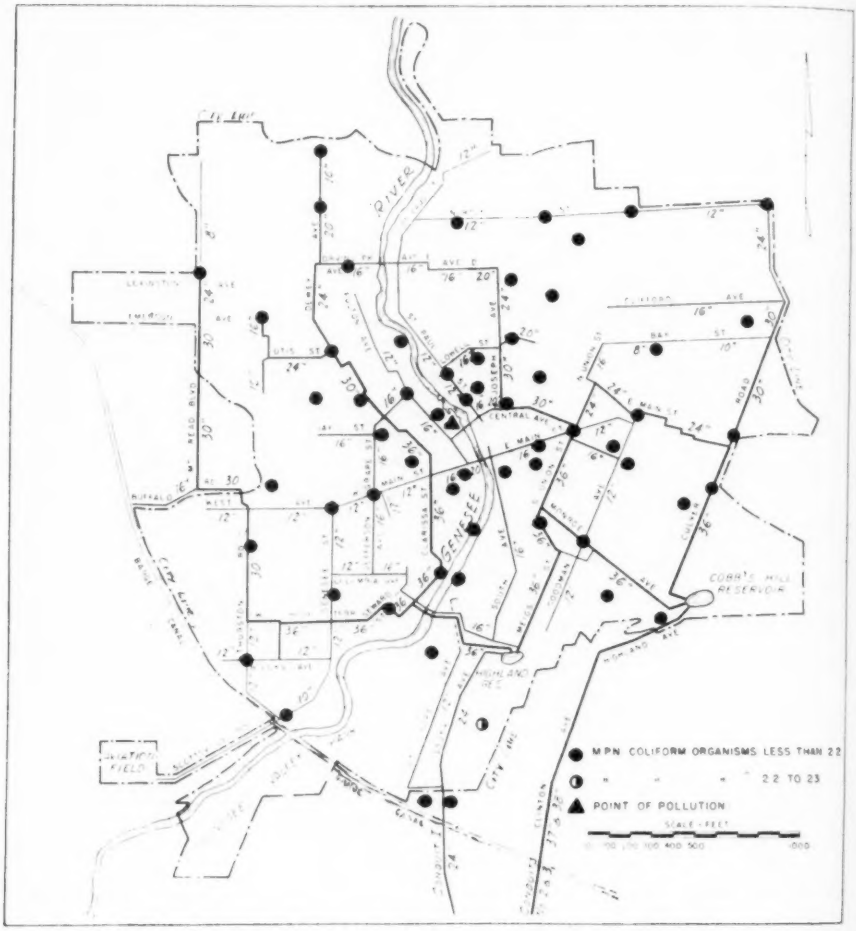

FIG. 13. Results of Bacteriological Tests of December 18

in connection with the occurrence have been filed against the city, with claims said to amount to about $200,000.

There were a number of factors that tended to alleviate the development of any extensive epidemic of typhoid, notwithstanding the

pollution of the public water supply, indicated by bacterial examinations of samples of water throughout the city, and the initial wave of gastro-enteritis among the city and county residents who gave a history of drinking Hemlock water without boiling immediately following the pollution of the public water supply system.

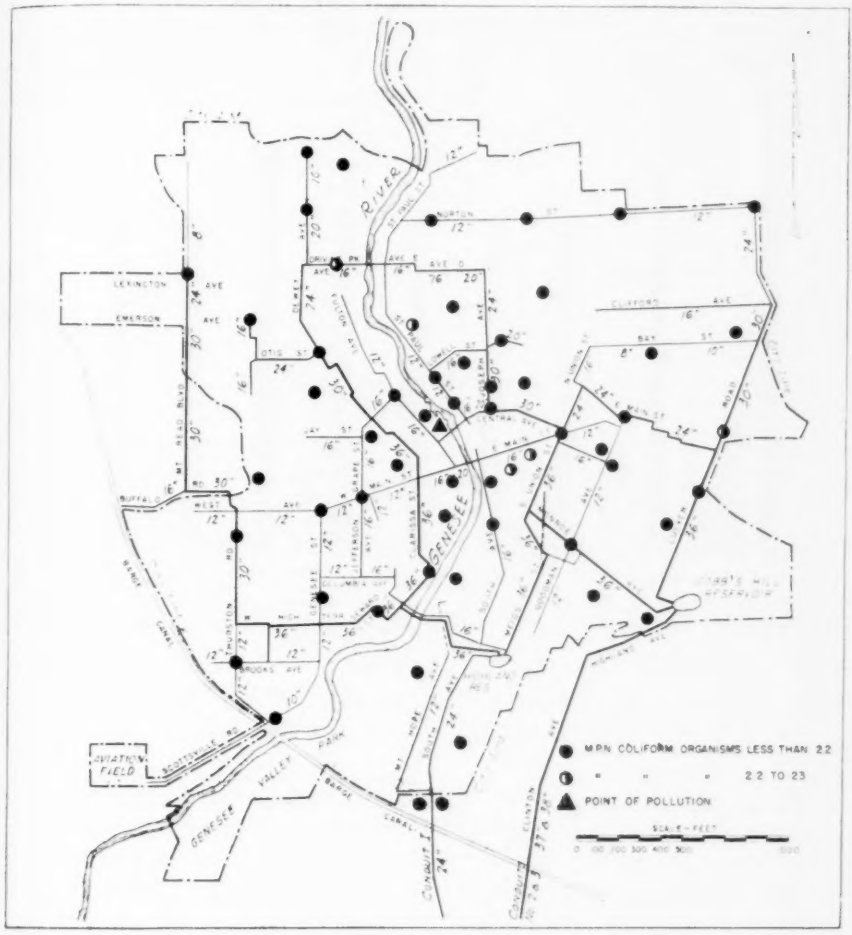

FIG. 14. Results of Bacteriological Tests of December 19

Department records indicate that the Genesee river receives sewage or sewage effluent from some 15 communities, of a total population of 34,000, located above the City of Rochester. Only three of these communities, having a population of 7,000, discharge their

sewage without treatment. In addition many small private systems from individual homes on such a large watershed discharge sewage or sewage effluent into the river or its tributaries. There were no known active cases of typhoid fever in the areas served by these sewer systems, but there were three known typhoid carriers on the water-

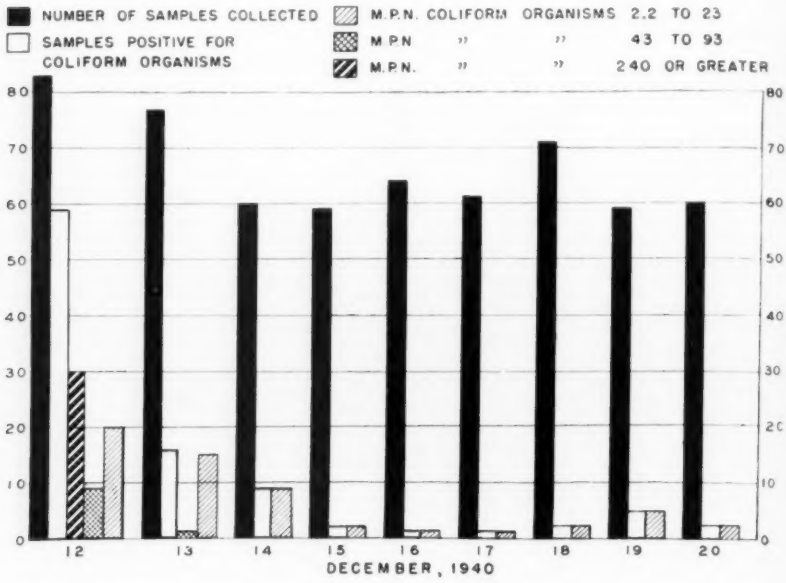

FIG. 15. Results of Bacteriological Tests of December 12 through 20

TABLE 3

Results of Bacterial Examinations

DATE	NO. OF SAMPLES EXAMINED	NO. OF SAMPLES NEGATIVE	NO. CONFIRMING	BREAKDOWN OF CONFIRMING SAMPLES IN M.P.N.															
				> 2400	> 240	240	93	62	43	23	15	13	9.1	8.8	6	5	4.6	3.6	2.2
Dec. 12	85	28	57	2	2	26	3	2	2	3	1	1	2	2		1		8	2
Dec. 13	77	61	16					1		3					10		2		
Dec. 14	60	51	9							2					6		1		
Dec. 15	58	56	2										1				1		
Dec. 16	64	63	1												1				
Dec. 17	61	60	1							1									
Dec. 18	71	69	2												2				
Dec. 19	59	54	5												5				
Dec. 20	60	58	2							1					1				

shed in the area served by systems discharging treated sewage. Two other carriers and one convalescent case resided in unsewered communities on the watershed. Undoubtedly there were unknown carriers who were living on or visiting the area, so that ample opportunity was afforded for the presence of typhoid bacilli in the raw Genesee river water.

Because of rains and melting snow, however, the river flow was high so that the pollution present was greatly diluted. The period during which the polluted water was available and used by the public, prior to the institution of corrective measures and warnings to the public that the water should be boiled, was comparatively brief, and the methods used to spread the notice of pollution were probably more extensive than any heretofore employed.

Plans for Abandonment of River Supply

Due to the uncertainty of the possible existence and location of cross-connections other than those shown in the water department records and the possibility of accidental future cross-connections between the Holly fire pressure system and the Hemlock public water supply system, it was felt that the continued use of river water as an auxiliary supply would be an ever present public health hazard to the safety and health of the citizens. The city administration was requested, therefore, to take immediate steps to provide for the abandonment of the use of river water as an auxiliary source of supply for the Holly high pressure fire supply. Before leaving the city, the author arranged for a conference between representatives of the city and engineers of various fire insurance interests to consider the problem. The fire insurance engineers were asked to study the problem with a view to formulating a plan that would provide for the permanent abandonment of the use of river water.

At a subsequent conference, held in New York City in the office of the chief engineer of the National Board of Fire Underwriters, between representatives of the city administration, the state department of health and engineers of the various fire insurance interests, a plan for abandoning the use of river water was agreed upon. This plan provides for the installation of a 3-mil.gal. covered storage reservoir to be supplied only with water from the Hemlock domestic water supply system and from which the fire pumps will take suction. The suction of the fire pumps will also be connected with the Hemlock System. At present, the Commissioner of Public Works and his engineers are preparing to carry out this change.

Summary

As an example of the imminent dangers of pollution of a public water supply this occurrence has occasioned widespread comment and discussion among water works officials and authorities throughout the entire country. It seems difficult to realize that such a disaster could occur in a large city with a long-established water department and staff of engineering and technical employees.

As a result of the Rochester experience, Dr. Edward S. Godfrey, State Commissioner of Health, has directed all water works authorities in the state to make a careful and thorough survey of their systems to eliminate all dangerous cross-connections, and has requested that a report on the surveys made and the results of their findings be submitted promptly. The results of these surveys have been quite surprising. Reports have shown the discovery of many heretofore unknown cross-connections. While the larger percentage of such connections have been of a minor nature, such as cross-connections with private household supplies, boilers, feed pumps, etc., over a hundred previously unknown or unrecognized connections with seriously polluted and highly dangerous supplies have been found.

Regrettable as the Rochester situation has been, it serves to indicate that constant and ever-watchful supervision must be maintained by those in responsible charge of all our public water supplies, to prevent the maintenance of dangerous cross-connections that may inadvertently or ignorantly be installed, if the occurrence of such outbreaks is to be obviated. It also serves to indicate the importance of the routine bacterial examinations of tap samples throughout the distribution system, as has been quite generally recognized and followed by the larger municipalities.

Survey of Water Main Extension Policies

By L. A. Jackson

IN AN effort to determine a general policy for the financing of water main extensions in cities of between 100,000 and 200,000 population, a questionnaire was sent to the 52 U. S. cities falling in that group, as ascertained from the 1940 census figures. Probably other plants serve populations within this range by reason of their rural and other community accounts, but this fact was not reflected in the census figures and, therefore, such municipalities were not included in the survey.

Perhaps in no other branch of the water works industry is practice so varied as it is in the methods used to finance water main extensions. This fact was demonstrated some years ago in a report (Jour. A. W. W. A., **30:** 1 (1938)) by the author on the data of more than 50 cities. In that report it was demonstrated that the cities, which varied greatly in size, showed no standard practice in their extension financing policies. It was expected that, in this survey, by confining the study to cities of one group size, the statistics would reveal a greater consistency of policy. As will be demonstrated in the following discussion, however, this is not the case, the same wide variations in practice being reported throughout.

Of the total of 52 questionnaires sent, 28, or 54 per cent, were returned. This return, though not as large as was expected, represented a good geographical distribution, New England, the East, the Middle West and the South each returning six, and the West, four. A summary of the data obtained from these replies is shown in Table 1.

As reported, 22 of the 28 cities have some type of extension financing plan, 17 of these using the "guaranteed revenue" type and the other five, the "assessment" type plan. In general, the assessment

A paper presented on June 26, 1941, at the Toronto Convention by L. A. Jackson, Manager, Little Rock Municipal Water Works, Little Rock, Ark.

TABLE 1

Summary of Data From Survey of Extension Financing Methods of 28 Cities of 100,000 to 200,000 Population

Number of cities with definite plan for financing extensions*.....		22
Guaranteed Revenue plan (guarantee of investment varies from 5 to 30%).....	17	
Assessment plan (assessments per foot vary from $0.60 to $2.00).....	5	
Number of cities with no definite plan.....		6
Number of cities in which funds for extensions are derived from:		
Water rates alone.....		9
Water rates combined with assessment, taxes or revenue bonds.....		13
Assessments, taxes and revenue bonds.....		6

	Yes	*No*
Extensions limited by budgeted appropriations.....	16	12
Capital expenditures account set up.....	22	6
Final decision on extensions rests with management.....	25	3
Separate plan for extensions beyond city limits.....	12	16
Mains beyond city limits.....	23	5

Number of cities in which consumer ownership and maintenance begins at:	
Street main.....	10
Curb.....	13
Property line.....	5
Average percentage of capital expenditures (all types) to gross revenue (19 plants reporting), *per cent*.....	9.4
Amount invested in all other supply facilities for each dollar in distribution mains.....	$0.40 to $2.57

	Yes	*No*
Ownership and title to mains extended remains with the department.....	28	0

Number of cities in which estimates on extensions are based on pipe of:	
Actual size required.....	6
2 in. to 6 in.....	2
6 in.....	10
8 in.....	4

	Yes	*No*
Department pays expense if larger sizes seem desirable.....	19	2
Bond required to guarantee revenue.....	3	—
Refunds made to applicant participating in cost of extension..	9	—
Total refunds made with no time limit.....	2	—

* Extension pipe sizes vary from 2 to 8 in.

TABLE 1—*continued*

Summary of Data From Survey of Extension Financing Methods of 28 Cities of 100,000 to 200,000 Population

Refunding contract periods, *yr*	2 to 12	
	Yes	*No*
Applicant for extension allowed special water rate during financing period	0	28
Interest paid on money advanced by applicant	0	28
Assessment periods, *yr*	3 to 15	
Number of cities in which assessments are based on pipe size of:		
6 in.		5
8 in.		1
	Yes	*No*
Interest charged on deferred assessment payments	6	0

type plan appears to be more sound, for in reducing it to a "return on investment" basis, it gave higher figures than those of the guaranteed revenue plans submitted.

The extent to which the water department should make capital expenditures for new mains which create new revenue is another of the questions which it was hoped the survey would answer. It must be pointed out, of course, that whether the money is obtained from taxes, assessments or rates, capital expenditures must always be on a sound basis.

From a study of the plans used, it would seem that the prevailing practice is for the department to furnish a portion of the funds, the consumer to pay the balance, and the department to make refunds to the consumer. The amount of money expended by the department is usually established by capitalizing the anticipated or guaranteed revenue on a gross per cent return basis. The majority of plants have a fixed requirement such as a percentage gross return that is considered by the management to warrant the expenditure.

It is granted that there are physical conditions, such as total plant investment, debt service requirements, operating ratios and plant growth, that would vary the requirements; but when financing plans are reported with guaranteed returns ranging from 9 to 30 per cent, the variation is difficult to explain. In this connection, the author

feels that it will be valuable, here, using the collected data as a guide, to attempt to list some of the major factors that affect any guaranteed return type of financing plan.

Before any fixed requirement is established all factors affecting the net return should be considered. Many managers lose sight of the fact that as their distribution system expands, their load and capacity demands increase and that at some future time large capital expenditures will be needed to make the pumping plant, filter plant, or primary supply system adequate.

The numerous small extensions are closely allied to the major projects of a water plant, and each should participate, proportionately, in the ultimate expense it will occasion. "Water works plants cannot be built in increments for one customer,"* but the ratio of water main investment to all other plant investment can be determined and used as a basis to ensure that each new water consumer requiring extension of water main facilities pay his proper share.

Investment Factor in Extensions

Replies to the questionnaire revealed that, for every dollar invested in distribution mains, from $0.40 to $2.57 are invested in all other supply facilities, the average probably falling a little below $2.00. Since most financing plans are based on gross revenue, a further adjustment should be made to take care of production expense. This is mostly easily done from the plant operating ratio.

Information concerning operating ratios was not collected in this survey; conservative estimates for plants in this group size, however, are that operating ratios on the average would fall between 30 and 50 per cent. An average operating ratio of 40 per cent, for instance, indicates that 40 per cent of gross revenue is required to meet operating expenses and 60 per cent is available for return.

Of the 28 cities reporting, 20 indicated that funds derived from water rates were reinvested in water main extensions. The original plant establishing these rates was probably financed with bonds carrying interest charges of between 4 and 6 per cent. Additions to the plant therefore, should at least yield a net return equivalent to the cost to finance them with borrowed money. If this practice is not followed, money derived from existing consumers will be used as a subsidy for new consumers who require plant additions for service.

* Berry, F. R. Financial Considerations of Distribution System Extensions. Jour. A. W. W. A., **33**: 1041 (1941).

Considering the above factors, and using average figures from the collected data, the problem of determining the percentage return on a gross revenue basis, that is necessary to finance water main extensions adequately, resolves itself somewhat as follows: (1) net return on investment required is 5 per cent; (2) investment on all other supply facilities for each dollar invested on distribution mains is $2; (3) adjusted return on this basis then becomes 3 × 5 per cent, or 15 per cent; (4) since operating ratios average about 40 per cent, then only 60 per cent of return is available; (5) adjusting return for this factor makes it $\frac{15 \text{ per cent}}{0.60}$, or 25 per cent.

If the minimum figures reported—4 per cent net, $0.40 per dollar investment and 30 per cent operating ratio—had been used throughout the problem, the gross return would have been 8 per cent; and, conversely, if the maximum figures—6 per cent net, $2.57 per dollar investment and 50 per cent operating ratio—had been used, gross return would have been 42.64 per cent. It is hardly probable that all minimum or maximum figures would ever prevail; therefore, the true answer lies between the two extremes and very likely near the 25 per cent figure.

It is interesting to observe that the results of several studies made by engineers representing both municipally and privately owned plants have come to approximately similar conclusions on this subject of water main financing. These facts are also recognized by some regulatory commissions, with the result that plans are now in force that embody the above principles.

Water works men want new business, but they should be certain that the new business is good business. A sound plan will not discourage real estate developments that have good potentialities, but will and should prevent investment of water works funds in undeveloped, non-revenue-producing territory.

The Control of Automotive Equipment

By Louis A. Geupel

IN THIS day and era, the management of every water works system realizes that the effective operation and maintenance of the plant and system depend largely on the promptness and economy with which service can be given to all parts of the system. The control and operation of the water department's automotive equipment, therefore, constitute a most important daily task which must be carried out smoothly and under strict supervision at all times. In these troublesome and expensive days serious consideration must be given not only to the operation and maintenance of the equipment itself but to the character and morale of the personnel. It becomes a most important task of supervision to make evident to the men who are involved in expediting materials, repairs, service and the operation of automotive equipment that they are working *with* rather than *for* the rest of the water works personnel.

With so many variables in the costs of items, such as gasoline, oil, tires, batteries, spare parts, etc., necessary to keep the cars and trucks of every water utility moving at the required time, the fixed unit of "miles per gallon" of gasoline used becomes most important. "Cost per mile," too, with or without fixed charges, such as insurance, depreciation, etc., is important if the cost of gasoline can be kept within a uniform range; and classification of similar types and tonnage of automotive equipment employed also becomes useful information. To obtain data of interest to all water works men, it thus becomes necessary to add the required practical facts to a simple type of record from which the accountants may obtain the information they require. It is believed that the effective control of water works automotive equipment is reflected in these several units of cost, and can be studied only in the comparison of the experience of others in the same field.

A paper presented on June 26, 1941, at the Toronto Convention by Louis A. Geupel, Superintendent, Water Works Department, Evansville, Ind.

It was realized that it would be impossible to obtain definite data on the subject from every utility in the water works field, so a method of selection, by which only those utilities in the U. S. which operate in cities of from 100,000 to 200,000 population were contacted, was derived. It was attempted, however, to obtain information from all water works utilities in Canada. Questionnaires requesting data on the costs of operation and maintenance of automotive equipment were forwarded to the utilities in these classifications.

Of the 44 U. S. city utilities contacted, 33, or 75 per cent, replied. In Canada 21 questionnaires were mailed and 19, or 90 per cent, returned. Information from the replies of 26 of the U. S. and 16 of the Canadian utilities were then tabulated for comparison (see Table 1 at end of paper).

Summary of Data on U. S. Utilities

Briefly, the information of the table, concerning U. S. utilities operating 660 cars, pick-up and heavy-duty trucks, which traveled 5,573,590 miles in 1940, may be summarized as follows:

1. Average miles per gallon for the 26 fleets of cars and trucks was 10.26, ranging from a minimum of 6.7 to a maximum of 13.10.

2. Average cost per mile, at the cost per gallon of gasoline actually paid by the water departments, was 3.078 cents, ranging from 1.62 to 6.8 cents.

3. Average cost per mile, adjusted to the cost per gallon of gasoline at 10 cents per gallon, for all fleets was 2.928 cents, ranging from 1.63 to 6.28 cents.

4. Cost of oil for the 26 fleets averaged 8.31 per cent of the gasoline costs, ranging from 4.3 to 17.2 per cent.

5. Repairs, tires and battery cost for the fleets averaged 51.7 per cent of the net cost, without insurance or depreciation, ranging from 34.4 to 74.4 per cent.

6. Insurance and depreciation, given for only four fleets, averaged 21.5 per cent of the net cost, ranging from 11.65 to 31.0 per cent.

7. Using actual costs as given, 136 cars, covering 1,137,873 mi. in 1940, averaged 12.76 mi. per gal., the minimum being 7.28 and maximum, 15.79 mi. per gal. Costs on this basis averaged 2.517 cents per mile, ranging from 1.4 to 5.27 cents.

8. Using actual costs as given, 183 ½-ton pick-up trucks, covering 1,888,856 mi. in 1940, averaged 11.48 mi. per gal., the minimum being 9.77 and maximum, 13.5 mi. per gal. Costs on this basis averaged 2.7 cents per mile, ranging from 1.5 to 4.9 cents.

9. Using actual costs as given, 13 ¾- and 1-ton trucks, covering 100,775 mi. in 1940, averaged 10.47 mi. per gal., the minimum being 9.33 and maximum, 11.98 mi. per gal. Costs on this basis averaged 2.8 cents per mile, ranging from 1.26 to 4.7 cents.

10. Using actual costs as given, 118 1½- to 3-ton trucks, covering 723,628 mi. in 1940, averaged 7.26 mi. per gal., the minimum being 5.92 and maximum, 9.86 mi. per gal. Costs on this basis averaged 4.43 cents per mile, ranging from 2.35 to 12.1 cents.

Using actual costs as given, 14 4- and 5-ton trucks, covering 128,822 mi. in 1940, averaged 6.54 mi. per gal., the minimum being 3.11 and maximum, 6.87 mi. per gal. Costs on this basis averaged 4.93 cents per mile, ranging from 2.0 to 11.3 cents.

Summary of Data on Canadian Utilities

The data derived from the replies of the utilities of Canadian cities and towns, which operated 186 cars, pick-up and heavy-duty trucks that traveled 1,489,685 mi. in 1940, may be summarized as follows:

1. Average miles per gallon* for the 16 fleets of cars and trucks was 9.65, ranging from a minimum of 7.08 to a maximum of 16.1.

2. Average cost per mile, at the cost per gallon of gasoline actually paid by the utilities, excluding the low Windsor costs, was 3.66 cents, ranging from 2.4 to 6.6. Including the Windsor cost of 1.4 cents per mile, the average was 3.43 cents.

3. Average cost per mile, adjusted to the cost per U. S. gallon of gasoline at 10 cents per gallon, for all fleets was 3.27 cents, excluding the Windsor cost of 1.2 cents per mile.

4. Cost of oil for the 16 fleets averaged 5.3 per cent of the gasoline costs, ranging from 3.0 to 11.7 per cent.

5. Repairs, tires, battery and miscellaneous cost for the fleets averaged 46.0 per cent of the net cost, without insurance or depreciation, ranging from 27.0 to 60.0 per cent.

6. Insurance and depreciation, given for eight fleets, averaged 67.0 per cent, ranging from 23.0 to 170 per cent. These figures, however, included Toronto and Windsor totals, which averaged 145 per cent. Excluding their figures, the average of the other six cities was only 41 per cent.

7. Using actual costs as given, cars, covering 401,403 mi. in 1940,

* All values in gallons throughout the discussion of the data on Canadian utilities refer to Imperial gallons unless otherwise noted. (1 Imperial gallon = 1.2 U. S. gallons.)

averaged 14.99 mi. per gal., the minimum being 10.3 and maximum, 17.5 mi. per gal. Costs on this basis averaged 4.12 cents per mile, ranging from 1.9 to 5.7 cents.

8. Using actual costs as given, ½-ton pick-up and light trucks, covering 251,775 mi. in 1940, averaged 12.07 mi. per gal., the minimum being 8.75 and maximum, 16.7 mi. per gal. Costs on this basis averaged 3.35 cents per mile, ranging from 2.1 to 3.8 cents.

9. Using actual costs as given, 1½-ton trucks, covering 729,653 mi. in 1940, averaged 9.45 mi. per gal., the minimum being 6.6 and maximum, 15.3 mi. per gal. Costs on this basis averaged 4.4 cents per mile, ranging from 1.22 to 5.3 cents.

10. Using actual costs as given, four heavy trucks, covering 41,233 mi. in 1940, averaged 8.77 mi. per gal. at an average cost per mile of 5 cents.

Recommendations

On the basis of the information discovered in this survey it is recommended:

1. That water utility managements keep a careful record of the control and maintenance of their automotive equipment, combining the physical equipment record with their regular accounting forms, so that a complete study can be made from the one source. The various units of equipment should be segregated on simple forms, showing mileage, amount and cost of gasoline and lubricating oil, cost of tires, cost of batteries and battery service, garage repair expense and miscellaneous other costs contributed to the total of net operating and maintenance expense. To these items could be added license, insurance and depreciation expense to form a second or grand total column for overall cost. On the same sheet, too, space could be left for the notation of miles per gallon, cost per mile, and other such computed information; and finally the cost per unit of gasoline and oil should always be listed on the form. In this connection it is recommended also that the American Water Works Association empower a committee to draw up such a simple form for the adoption of utility managements, so that the information of all records could be drawn up consistently.

2. That every supervisor of water utility fleets of automotive equipment study his own conditions with a view toward expediting service and toward realizing the greatest economies of operation and maintenance.

TABLE 1

Data on Cost of Automotive Equipment in Water Utilities of U. S. Cities of 100,000 to 200,000 Population and of Canadian Cities and Towns

AUTOMOTIVE EQUIPMENT	NO.	TOTAL MILEAGE —1940	MILEAGE PER GALLON	COST PER MILE EXCLUDING INSURANCE AND DEPRECIATION		COST PER MI. INC. INS. & DEPN.	PERCENTAGE OF TOTAL COST EXPENDED FOR REPAIRS, TIRES, BATTERIES, ETC.
				At given price	At 10¢ per gal.		
		mi.	*mi.*	¢	¢	¢	%
U. S. CITIES							
Worcester, Mass.—Gasoline, 9.7¢							
Total Fleet	22	160,897	7.45	6.26	6.28	8.06[1]	74.4
Cars	5	35,765	10.31	4.7			
Pick-up trucks	2	14,192	9.17	4.9			
¾- to 1-ton trucks	4	50,194	9.33	4.7			
1½- to 2-ton trucks	9	54,148	5.94	8.4			
4-ton trucks	2	6,598	3.11	11.3			
Evansville, Ind.—Gasoline, 14¢							
Total Fleet	24	197,941	10.8	3.884	3.51		34.4
Cars	3	34,609	15.79	2.8			
Pick-up trucks	13	120,887	11.71	3.43			
1½- to 2-ton trucks	8	42,445	7.35	5.9			
Sacramento, Calif.—Gasoline, 11.28¢							
Total Fleet	22	146,385	13.1	2.327	2.227		60.5
Cars	8	48,758	13.79	1.817			
Pick-up trucks	13	91,688	13.5	2.116			
2-ton trucks	1	5,939	6.96	8.44			
Tacoma, Wash.—Gasoline, 15.4¢							
Total Fleet	36	398,685	12.29	3.721	3.265	4.88[2]	36.0
Cars	13	155,434	14.92	2.99			
Light trucks	21	220,081	10.83	14.24			
Heavy trucks	2	23,170	6.77	4.07			
Nashville, Tenn.—Gasoline, 11¢							
Total Fleet	25	175,092	11.28	1.72	1.63		37.0
Cars	10	88,334	12.96	1.5			
Trucks	15	86,758	9.86	1.97			

[1] Depreciation and insurance, 28.5% of net cost.

[2] Depreciation, 31% of net cost.

TABLE 1—*Continued*

AUTOMOTIVE EQUIPMENT	NO.	TOTAL MILEAGE —1940	MILEAGE PER GALLON	COST PER MILE EXCLUDING INSURANCE AND DEPRECIATION		COST PER MI. INC. INS. & DEPN.	PERCENTAGE OF TOTAL COST EXPENDED FOR REPAIRS, TIRES, BATTERIES, ETC.
				At given price	At 10¢ per gal.		
		mi.	*mi.*	¢	¢	¢	%
U. S. CITIES—*Continued*							
Youngstown, Ohio—Gasoline, 10.77¢							
Total Fleet	37	295,390	10.3	3.16	3.09	3.63[3]	63.7
Cars (coupes)	12	100,175	11.6	2.93			
Pick-up trucks	13	129,647	10.2	3.03			
¾-ton trucks	8	41,079	11.98	2.56			
1½- to 2-ton trucks	4	24,489	6.39	5.77			
Fort Wayne, Ind.—Gasoline, 14.4¢							
Total Fleet	20	135,644	10.03	3.26	2.83	3.64[4]	50.0
Cars (coupes)	3	25,630	11.65	2.81			
½-ton pick-up trucks	11	77,340	10.06	3.15			
1- to 3-ton trucks	6	32,674	8.97	3.89			
Tulsa, Okla.—Gasoline, 10¢							
Total Fleet	42	159,678	9.6	1.91	1.91		40.6
Cars (coupes & sedans)	15	75,732	9.98	1.26			
½-ton pick-up trucks	8	46,840	10.33	1.5			
¾-ton trucks	4	9,502	9.98	1.26			
1- to 3-ton trucks	15	27,604	5.92	3.05			
Chattanooga, Tenn.—Gasoline, 17¢							
Total Fleet	15	246,787	12.15	3.374	2.759		38.0
Cars (coupes)	9	146,660	14.0	2.9			
½-ton pick-up trucks	2	33,252	11.0	3.58			
1½-ton trucks	4	66,874	9.75	4.33			
Knoxville, Tenn.—Gasoline, —							
Total Fleet	31	404,471		2.21		7.68	45.5
Cars	8	96,554		1.51			
Pick-up trucks	11	175,605		1.87			
¾-ton truck	1	790		0.8			
1½- to 2-ton trucks	11	131,522		3.16			

[3] Depreciation 14.6% of net cost.

[4] Depreciation 11.65% of net cost.

TABLE 1—*Continued*

AUTOMOTIVE EQUIPMENT	NO.	TOTAL MILEAGE —1940	MILEAGE PER GALLON	COST PER MILE EXCLUDING INSURANCE AND DEPRECIATION		COST PER MI. INC. INS. & DEPN.	PERCENTAGE OF TOTAL COST EXPENDED FOR REPAIRS, TIRES, BATTERIES, ETC.
				At given price	At 10¢ per gal.		
		mi.	*mi.*	¢	¢	¢	%
U. S. CITIES—*Continued*							
Flint, Mich.—Gasoline, 6.75¢							
Total Fleet	23	190,183	10.68	2.75	3.0		73.0
Cars	7	59,123	13.7	2.65			
½-ton pick-up trucks	9	88,051	11.6	2.37			
1½-ton trucks	6	39,384	8.15	3.09			
5-ton truck	1	3,630	4.0	5.37			
Des Moines, Iowa—Gasoline, 9.25¢							
Total Fleet	43	283,583	10.34	3.22	3.28		69.5
Cars	10	39,381	11.48	5.27			
½-ton pick-up trucks	23	200,239	11.55	1.92			
Other trucks	10	43,963	6.61	7.68			
Salt Lake City, Utah—Gasoline, 14¢							
Total Fleet	40	506,620	10.89	2.00	1.86		38.5
Cars (coupes & sedans)	9	107,818	13.77	2.			
½-ton pick-up trucks	20	299,432	10.6	1.95			
1½-ton trucks	10	96,168	8.78	3.22			
3-ton truck	1	3,202	4.6	6.			
Duluth, Minn.—Gasoline, 12.55¢							
Total Fleet	34	304,075	9.8	4.07	3.746		66.0
Cars	7	54,653	13.67	4.03			
½-ton pick-up trucks	15	168,243	11.6	2.57			
1½- to 3-ton trucks	12	81,179	6.5	6.64			
Richmond, Va.—Gasoline, 12.5¢							
Total Fleet	27	291,598	11.6	2.09	1.902		50.0
Cars	9	90,298	12.5	2.05			
½-ton pick-up trucks	11	149,483	12.4	1.78			
Other trucks	7	51,817	8.8	3.			

TABLE 1—*Continued*

AUTOMOTIVE EQUIPMENT	NO.	TOTAL MILEAGE—1940	MILEAGE PER GALLON	COST PER MILE EXCLUDING INSURANCE AND DEPRECIATION		COST PER MI. INC. INS. & DEPN.	PERCENTAGE OF TOTAL COST EXPENDED FOR REPAIRS, TIRES, BATTERIES, ETC.
				At given price	At 10¢ per gal.		
		mi.	*mi.*	¢	¢	¢	%
U. S. CITIES—*Continued*							
Hartford, Conn.—Gasoline, 11.3¢							
Total Fleet	42	475,594	9.33	3.59	3.47		68.0
Cars (sedans)	7	67,423	7.78	4.04			
½-ton pick-up trucks	20	249,481	12.3	2.2			
1½- to 2-ton trucks	6	43,939	8.32	5.38			
4-ton trucks	9	114,751	6.87	4.79			
Elizabethtown, N. J.—Gasoline, 14¢							
Total Fleet[5]	22	231,392	12.79	2.57	2.26		45.8
Grand Rapids, Mich.—Gasoline, 8¢							
Total Fleet[5]	32	15,825	7.8	3.18	3.45		67.0
Scranton, Pa.—Gasoline, 12.5¢							
Total Fleet[5]	46	444,715	8.7	4.6	3.64		37.7
Norfolk, Va.—Gasoline, 6.8¢							
Total Fleet[5]	17	199,343	10.35	1.62	1.93		56.5
Trenton, N. J.—Gasoline, 6.4¢							
Total Fleet[5]	8	136,790	8,796	2.32	2.72		64.0
Tampa, Fla.—Gasoline, 14¢							
Total Fleet[5]	14	85,857	10.57	2.7	2.33		44.2
Gary, Ind.[6]—Gasoline, —							
Total Fleet	6	4,557	6.7	6.8	4.52		
½-ton pick-up trucks	3	2,871	8.9	3.8			
1½-ton trucks	3	1,636	4.7	12.1			

[5] Type and weight of cars and trucks not given.

[6] Data for 1 month only.

TABLE 1—*Continued*

AUTOMOTIVE EQUIPMENT	NO.	TOTAL MILEAGE —1940	MILEAGE PER GALLON	COST PER MILE EXCLUDING INSURANCE AND DEPRECIATION		COST PER MI. INC. INS. & DEPN.	PERCENTAGE OF TOTAL COST EXPENDED FOR REPAIRS, TIRES, BATTERIES, ETC.
				At given price	At 10¢ per gal.		
		mi.	*mi.*	¢	¢	¢	%
U. S. CITIES—*Concluded*							
Springfield, Mass.—Gasoline, 10.5¢							
Total Fleet	21	13,291	9.94	1.89	1.8		37.0
Cars (coupes & sedans)	9	8,080	11.6	1.41			
¾- to 1-ton trucks	3	1,493	9.0	3.58			
1½-ton trucks	8	3,077	8.34	2.25			
5-ton trucks	1	641	6.0	2.			
Jacksonville, Fla.—Gasoline, —							
Total Fleet[7]	11	90,824		2.79			46.0
Cars (coupes)	2	19,058		1.99			
½-ton pick-up trucks	2	23,908		2.			
1½-ton trucks	7	47,858		3.93			
Utica, N. Y.[6]—Gasoline, —							
Total Fleet[5]	19	12,752	10.87	2.17		4.68	30.24
CANADIAN CITIES[8]							
Toronto, Ont.—Gasoline, for trucks, 14¢, for cars 21.4¢							
Total Fleet	23	223,096	12.88	2.4	2.07	5.3[9]	44.2
Cars (sedan coaches)	7	86,025	17.05	1.9			
½- and ¾-ton trucks	7	64,939	13.76	2.1			
1½-ton trucks	9	72,132	9.55	3.2			
Victoria, B. C.—Gasoline, 24¢							
Total Fleet	4	44,487	13.47	3.1	2.27		39.2
Car (coupe)	1	10,872	14.19	2.8			
Trucks	3	33,615	13.5	3.47			
Vancouver, B. C.—Gasoline, 24.7¢							
Total Fleet[10]	18	154,760	12.44	3.24	2.28		
½-ton delivery truck	1	22,128	15.50	2.64			
1- to 1½-ton trucks	9	91,399	8.62	4.69			
2- to 2½-ton trucks	4	41,233	8.77	5.05			

[7] Two cars not reported.

[8] Gasoline prices for Canadian cities are on the basis of the Imperial gallon (1.2 U. S. gallons).

[9] 120% of net cost.

[10] Four of the trucks had no speedometers, so no data are given for them.

TABLE 1—*Continued*

AUTOMOTIVE EQUIPMENT	NO.	TOTAL MILEAGE —1940	MILE-AGE PER GALLON	COST PER MILE EXCLUDING INSURANCE AND DEPRECIATION		COST PER MI. INC. INS. & DEPN.	PERCENT-AGE OF TOTAL COST EXPENDED FOR REPAIRS, TIRES, BATTERIES, ETC.
				At given price	At 10¢ per gal.		
		mi.	*mi.*	¢	¢	¢	%
CANADIAN CITIES[8]—*Continued*							
Kitchener, Ont.—Gasoline, 18¢							
Total Fleet (1½-ton truck)	1	8,500	7.08	3.16	2.46		27.2
Regina, Sask.—Gasoline, 23.5¢							
Total Fleet	22	201,882	10.4	4.5	3.46	5.71[11]	51
Cars	4	45,557	19.3	2.3			
1- to 1½-ton trucks	18	156,325	9.2	5.2			
York Township, Ont.—Gasoline, 22.5¢							
Total Fleet	3	36,289	12.2	3.4	2.53		48.3
½-ton pick-up truck	1	20,408	13.1	3.1			
1½- to 2-ton trucks	2	15,881	11.2	3.64			
Saskatoon, Sask.—Gasoline, 28.25¢							
Total Fleet (light trucks)	2	22,869	16.1	2.7	1.73		32.5
Winnepeg, Man.—Gasoline, —							
Total Fleet	16[12]						
Halifax, N. S.—Gasoline, —							
Total Fleet (truck)	1	23,507		2.79		4.18[13]	41.4
London, Ont.—Gasoline, 14.5¢							
Total Fleet	39	261,451	7.8	4.2	3.87	5.49[14]	54.5
Cars (coupes & sedans)	7	57,078	10.8	4.3			
½- to ¾-pick-up trucks	20	102,320	8.05	3.8			
1- to 3-ton trucks	12	102,053	6.73	4.6			

[11] 27% of net cost.
[12] No further data given.
[13] 50% of net cost.
[14] 30% of net cost.

TABLE 1—*Concluded*

AUTOMOTIVE EQUIPMENT	NO.	TOTAL MILEAGE —1940	MILEAGE PER GALLON	COST PER MILE EXCLUDING INSURANCE AND DEPRECIATION		COST PER MI. INC. INS. & DEPN.	PERCENTAGE OF TOTAL COST EXPENDED FOR REPAIRS, TIRES, BATTERIES, ETC.
				At given price	At 10¢ per gal.		
		mi.	*mi.*	¢	¢	¢	%
CANADIAN CITIES[8]—*Concluded*							
Edmonton, Alta.—Gasoline, 28¢							
Total Fleet	10	93,920	12.8	4.86	3.61	7.08[15]	54.5
Cars (coupes & light trucks)	8	77,318	13.2	3.96			
1½- to 1½-ton trucks	2	16,602	9.01	5.3			
Windsor, Ont.—Gasoline, 14.5¢							
Total Fleet	16	107,187	15.6	1.37	1.22	3.74[16]	32.4
Cars & pick-up trucks	13	90,282	15.7	1.39			
1- to 1½-ton trucks	3	16,905	15.3	1.22			
Quebec, Que.—Gasoline, 23¢							
Total Fleet	6	47,556	7.75	6.59	5.19	8.1[17]	53.0
Cars	2	16,883	11.14	5.71			
Light trucks	4	30,673	6.6	7.08			
Hamilton, Ont.—Gasoline, 15.7¢							
Total Fleet	3	32,633	13.04	3.38	3.37		60.2
½-ton trucks	2	20,000	14.3	2.9			
1½-ton truck	1	12,633	11.38	4.13			
Calgary, Alta.—Gasoline, 17.4¢							
Total Fleet	13	150,326	13.7	3.1	2.68	5.27[18]	53.5
Cars & light delivery trucks	5	71,388	17.5	3.2			
1½-ton trucks	8	78,938	10.2	3.61			
Ottawa, Ont.—Gasoline, 21.85¢							
Total Fleet[5]	13	93,997	11.05	4.37	3.48		53.0

[15] 45% of net cost.
[16] 170% of net cost.
[17] 23% of net cost.
[18] 70% of net cost.

Meter Reading and Commercial Department Operation

By Kenneth K. King

THIS paper deals entirely with costs of meter reading and commercial department expense of water departments in cities of the United States of populations between 80,000 and 220,000 according to the 1940 census.

There are 67 cities of the class described, and information for the year 1940 has been obtained from 47 for meter reading costs and 37 for commercial department expense. The most interesting of the data have been tabulated (Tables 1 and 2) and there is little that can be added to these tables that is not apparent to every water works man.

Additional questions to those tabulated were asked of each operator, but the answers were so varied in some cases and so uniform in others that they have little significance. Somerville and Cambridge, Mass., were the only two of the cities that replied which use hand billing, all others using machines.

Both for meter reading and commercial department data the cities are divided into three groups; northern cities, southern, and those cities reporting which have combined utility operation of water and electricity or water and gas. The average commercial department expenses for the three groups vary little, either in totals, per person, or per active service, but do differ greatly in average cost per bill. The average annual commercial expense per service for the 37 cities is $1.57, the northern group being 1 per cent lower, and the southern group 6 per cent higher. The average expense per bill is 22.7 cents, the northern cities being 78 per cent higher, and the other groups each being 26 per cent lower than the average of all. The billing periods in the north are such that only about one-third as many

A paper presented on June 26, 1941, at the Toronto Convention by Kenneth K. King, Director, Water Department, Kansas City, Mo.

Commercial Department Data of 87 U. S. Citie

CITIES	POPULATION INCLUDING SUBURBS	ACTIVE SERVICES	ACTIVE METERED SERVICES	COMMERCIAL EXPENSE	NO. EMPLOYEES	ANNUAL COST PER ACTIVE SERVICE	ANNUAL COST PER PERSON SERVED
Northern							
Cambridge, Mass.	111,000	14,325	13,873	$27,234.00	13	$1.90	$0.24
Canton, Ohio	112,000	28,500	28,500	57,123.64	24	2.00	.51
Des Moines, Iowa	116,281	37,231	37,047	70,750.00	23	1.90	.60
Evansville, Ind.	112,000	25,051	25,051	42,828.00	20	1.71	.38
Grand Rapids, Mich.	208,000	42,000	42,000	31,319.00	22	.75	.15
Hartford, Conn.	232,000	30,897	29,870	48,000.00	17	1.55	.20
New Bedford, Mass.	122,000	17,650	17,400	22,600.00	15	1.28	.18
New Haven, Conn.	263,000	50,176	30,893	68,660.00	38	1.37	.26
Rockford, Ill.	90,000	20,000	20,000	18,180.00	12	.91	.20
Saginaw, Mich.	83,294	18,234	18,223	27,740.28	17	1.52	.33
Somerville, Mass	100,000	13,882	13,797	16,782.00	11	1.22	.16
South Bend, Ind.	101,000	24,852	24,815	49,586.94	20	2.00	.49
Spokane, Wash.	123,462	38,529	32,549	33,401.04	18	.87	.27
Syracuse, N. Y.	213,000	39,190	37,190	51,230.00	29	1.31	.24
Tacoma, Wash.	112,408	33,523	9,614	51,053.97	17	1.52	.45
Trenton, N. J.	165,000	33,000	13,678	48,037.00	20	1.46	.29
Utica, N. Y.	117,000	25,575	21,646	27,679.00	17	1.08	.23
Youngstown, Ohio	175,000	34,000	33,000	64,067.56	24	1.88	.36
Total, 18 cities	2,556,445	493,092	449,146	$756,272.43	357		
Average	142,025	27,394	24,953	$42,015	20	$1.55	$.29
Southern							
Charlotte, N. C.	106,800	18,203	18,203	$36,067.34		$1.98	$.33
El Paso, Tex.	115,000	16,100	16,100	39,940.00	16	2.48	.34
Jacksonville, Fla.	175,000	32,891	32,891	70,647.58	32	2.15	.40
Little Rock, Ark.	114,280	18,909	18,909	29,250.00	22	1.55	.25
Nashville, Tenn.	194,065	38,813	38,813	46,876.03	31	1.21	.24
Norfolk, Va.	173,000	32,751	29,928	41,005.14	22	1.25	.23
Oklahoma City, Okla.	205,000	38,930	38,500	59,556.00	34	1.53	.29
Pasadena, Calif.	100,300	28,865	28,865	54,210.00	25	1.88	.54
San Diego, Calif.	209,178	48,646	48,646	70,153.00	35	1.44	.33
Tampa, Fla.	135,000	21,806	21,099	42,986.06	25	1.97	.31
Total, 10 cities	1,527,623	295,914	291,954	$490,691.15	242		
Average	152,762	29,591	29,195	$49,069	27	$1.66	$.33
Combined Water and Electric or Gas Utilities							
Duluth, Minn.	101,065	19,310	19,310	$32,061.00		$1.65	$.33
Fort Wayne, Ind.	118,410	29,483	29,483	43,000.00	24	1.45	.36
Glendale, Calif.	85,257	21,124	21,124	39,990.77	51	1.89	.47
Kansas City, Kan.	122,000	29,592	28,178	68,824.40	31	2.33	.56
Lincoln, Neb.	82,000	21,810	19,902	23,161.74	23	1.06	.28
Omaha, Neb.	223,844	53,774	53,170	63,100.00	46	1.17	.28
Scranton, Pa.	255,650	44,568	36,993	47,559.62	29	1.07	.19
Knoxville, Tenn.	151,829	29,505	24,893	38,695.60		1.31	.25
Long Beach, Calif.	169,300	34,993	34,993	79,294.86	42	2.32	.47
Total, 9 cities	1,309,355	284,159	268,046	$435,687.99	246		
Average	145,483	31,573	29,783	$48,410	35	$1.62	$.33
Total, all cities	5,393,423	1,073,165	1,009,146	$1,682,651.57	845		
Average, all cities	145,768	29,004	27,274	$45,477	25	$1.57	$.32

TABLE 1

U. S. Cities of 80,000 to 220,000 Population for the Year 1940

ANNUAL COST PER ACTIVE SERVICE	ANNUAL COST PER PERSON SERVED	NUMBER OF BILLS PER YEAR	COST PER BILL	METHOD OF BILL DELIVERY	TYPE OF ACCOUNTING SYSTEM	PENALTY ASSESSED FOR DELINQUENCY	RIGID SHUT OFF RULE	DISCOUNT ALLOWED FOR PROMPTNESS	PER CENT DELINQUENT
$1.90	$0.24	57,000	$0.478	2¢ Letter	Stub	$1.00 on & off	No	No	5
2.00	.51	114,000	.501	1¢ Card	Stub & ledger	No	No	10%	10
1.90	.60	152,493	.464	2¢ Letter	Ledger	No	No	No	1
1.71	.38	100,000	.428	Hand	Stub	No	No	No	5
.75	.15	170,000	.184	1¢ Card	Ledger	Yes	Yes	No	8½
1.55	.20	65,000	.738	2¢ Letter	Stub	Yes	Yes	No	2
1.28	.18	33,000	.685	2¢ Letter	Ledger	Yes	No	No	2
1.37	.26	153,329	.448	2¢ Letter	Card	$1.00 turn on	No	No	2
.91	.20	80,000	.227	1¢ Card	Ledger	No	No	5%	5
1.52	.33	75,000	.370	Hand	Ledger	5%	Yes	No	25
1.22	.16	55,200	.304	2¢ Letter	Combination	No	No	No	20
2.00	.49	99,408	.499	2¢ Letter	Ledger	No	No	10% & 3%	6
.87	.27	122,100	.274	2¢ Letter	Ledger	No	Yes	No	15
1.31	.24	165,000	.310	1¢ Card	Ledger	5%	No	No	7½
1.52	.45	115,200	.443	2¢ Letter	Ledger	No	No	No	4
1.46	.29	93,356	.515	2¢ Ltr. & hd.	Stub	No	Yes	Yes	
1.08	.23	91,764	.302	1¢ Card	Stub	No	No	2%	1
1.88	.36	129,000	.497	1¢ Card	Stub	No	No	10%	10
		1,870,850							
$1.55	$.29	103,936	$.405	14% Hand 86% Mail	55% Ledger 45% Stub	61% No 39% Yes	65% No 35% Yes	67% No 33% Yes	
$1.98	$.33	220,000	$.164	1¢ Card	Ledger	Yes	No	Yes	2 3/10
2.48	.34	195,000	.205	Hand	Stub	No	Yes	No	5
2.15	.40	400,000	.177	2¢ Letter	Ledger	Seldom	Yes	No	
1.55	.25	229,000	.127	1¢ Card & hd.	Stub	10%	Yes	No	7
1.21	.24	143,000	.328	Hand	Ledger	50¢ shut off	Yes	No	2
1.25	.23	120,000	.341	1¢ Card	Stub	$1.00 on	Yes	No	10
1.53	.29	444,000	.134	2¢ Ltr. & hd.	Stub	10%	Yes	No	4¾
1.88	.54	346,000	.157	2¢ Ltr. & hd.	Stub	$1.00 on & off	No	No	20
1.44	.33	583,656	.120	1¢ Card	Stub	10%	Yes	No	3
1.97	.31	253,500	.170	2¢ Letter	Ledger	No	Yes	10%	12
		2,934,156							
1.66	$.33	293,416	$.167	35% Hand 65% Mail	40% Ledger 60% Stub	20% No 80% Yes	20% No 80% Yes	80% No 20% Yes	
1.65	$.33	313,201	$.102	2¢ Letter	Stub	Yes	Yes	No	15
1.45	.36	360,000	.119	Hand	Ledger	No	Yes	No	
1.89	.47	253,500	.158	2¢, 3¢ & hd.	Stub & ledger	No	Yes	No	
2.33	.58	338,000	.204	1¢ Card	Ledger	5%	Yes	No	18
1.06	.28	245,000	.095	Hand	Stub	5%	Yes	No	18
1.17	.28	221,200	.285	1¢ Card	Ledger	Yes	No	No	10
1.07	.19	156,000	.305	Hand	Stub	No	No	No	15
1.31	.23	300,000	.129	2¢ & hd.	Stub	10% on 4000 cu. ft.	Mod.	No	3
2.32	.47	410,500	.193	1¢ Card	Ledger	No	No	No	15
		2,597,401							
.62	$.33	288,600	$.168	44% Hand 56% Mail	50% Ledger 50% Stub	44% No 56% Yes	50% No 50% Yes	100% No	
		7,402,407							
.57	$.33	200,065	$.227	25% Hand 75% Mail	50% Ledger 50% Stub	49% No 51% Yes	51% No 49% Yes	78% No 22% Yes	

TABLE 2

Meter Reading Data of 47 U. S. Cities of 80,000 to 220,000 Population for the Year 1940

CITIES	POPULATION INCLUDING SUBURBS	ACTIVE SERVICES	ACTIVE METERED SERVICES	METER READING PERIOD	NO. READERS	TOTAL READINGS PER YEAR	READINGS PER YEAR PER READER	ANNUAL SALARY READERS	ANNUAL READER COST PER METERED SERVICE	AVERAGE READER COST PER METER READING	PERCENTAGE OF CUSTOMER OWNED METERS	PERCENTAGE OF METERS IN BASEMENTS	PERCENTAGE OF METERS IN OUTSIDE BOXES	BEARER OF METER REPAIR COSTS
Northern														
Altoona, Pa.	88,000	20,000	20,000	Quarterly	3	80,000	28,333	$4,500	$0.225	$0.056	100	99	1	Dept.*
Bridgeport, Conn.	214,700	36,401	13,900	Mo. & qty.	5	61,600	12,320	8,400	.604	.136	0	75	25	Dept.
Cambridge, Mass.	111,000	14,325	13,873	Quarterly	8	54,000	6,750	17,472	1.259	.323	0	97	3	Dept.
Canton, Ohio	112,000	28,500	28,500	Mo. & qty.	7	118,000	16,857	9,240	.324	.078	0	98	2	Dept.*
Des Moines, Iowa	168,281	37,231	37,047	Mo. & qty.	6	165,868	27,644	10,440	.282	.062	0	75	25	Dept.
Evansville, Ind.	112,000	25,051	25,051	Mo. & qty.	6	104,200	32,366	8,892	.355	.085	0	12	88	Dept.
Fall River, Mass.	116,000	13,000	13,000	Quarterly	7	52,000	7,428	11,900	.915	.228	10	100	0	Dept.*
Flint, Mich.	140,500	35,206	35,206	Mo. & qty.	3	145,224	48,400	5,000	.142	.034	99.5			Dept.*
Grand Rapids, Mich.	208,000	42,000	42,000	Quarterly	5	168,000	33,600	6,780	.161	.04	0	92	8	Dept.
Hartford, Conn.	232,000	30,897	29,870	Bi-monthly	6	180,000	30,000	12,480	.418	.105	0	90	10	Dept.
Lowell, Mass.	105,000	15,300	15,000	Quarterly	5	60,000	12,000	9,240	.616	.154	90	99	1	Dept.*
New Bedford, Mass.	122,000	17,650	17,400	Monthly	9	208,800	23,200	11,794	.678	.056	8	97	3	Dept.*
New Haven, Conn.	263,000	50,176	30,893	Mo. & qty.	5	129,572	25,914	6,120	.198	.047	0	98	2	Dept.*
Reading, Pa.	125,000	27,701	27,701	Mo. & qty.	5	115,420	23,084	7,200	.259	.062	0			Consumer
Rockford, Ill.	90,000	20,000	20,000	Quarterly	3	80,000	26,666	4,140	.207	.051	100	99	1	Dept.*
Saginaw, Mich.	83,294	18,234	18,223	Mo. & qty.	2	73,236	36,618	3,216	.176	.043	0	96	4	Dept.*
Salt Lake City, Utah	155,000	33,800	33,800	Mo. & qty.	3	141,600	47,200	4,680	.138	.033	0	18	82	Dept.
Somerville, Mass.	100,000	13,882	13,797	Mo. & qty.	3½	55,200	18,400	5,880	.426	.106	0	94	6	Dept.
South Bend, Ind.	101,000	24,852	24,815	Mo. & qty.	4	100,740	25,185	5,760	.232	.057	0	80	20	Consumer
Spokane, Wash.	123,462	32,549	32,549	Mo. & 4 mo.	5	122,100	24,400	7,680	.236	.062	99.6	84	16	Dept.*
Syracuse, N. Y.	213,000	39,190	37,190	Mo. & qty.	9	152,760	12,730	12,716	.342	.083	100	99.8	0.2	Consumer

Spokane, Wash....	125,402	32,949	32,949	Mo. & 4 mo.	8	122,160	24,432	12,000	.491	.098	100	99.8	0.2	Consumer
Syracuse, N. Y....	213,000	39,190	37,190	Mo. & qty.	9	152,760	12,730	12,716	.342	.083	100	99.8	0.2	Consumer
Tacoma, Wash.....	112,408	33,523	9,614	Monthly	2	115,368	48,069	4,800	.499	.041	6	0	100	Dept.
Trenton, N. J.....	165,000	33,000	13,678	Quarterly	9	54,712	6,079	16,848	1.231	.30	0	67	33	Dept.*
Utica, N. Y.....	117,000	25,575	21,646	Mo. & qty.	4	94,160	23,540	4,800	.221	.05	0	99	1	Dept.*
Youngstown, Ohio.	175,000	34,000	33,000	Quarterly	6	132,000	22,000	9,828	.298	.074	100	98	2	Dept.*
Total, 25 cities....	3,552,645	702,043	607,753		131	2,764,560	618,783	$209,806						
Average.....	142,105.8	28,082	24,310	Mo. 8% Qty. 32% Mo. & qty. 52% Mo. 4 mo. 4% Bi-mo. 4%	5¼	110,582	24,751	8,392	$.345	$.076	32	82	18	88% Dept.
Southern														
Charlotte, N. C...	106,800	18,203	18,203	Monthly	4	218,436	54,609	$6,000	$.329	$.027	100	0.1	99.9	Dept.
Chattanooga, Tenn.....	153,063	30,033	29,814	Monthly	7	357,744	51,106	10,500	.349	.029	0	0.1	99.9	Dept.
El Paso, Tex.....	115,000	16,100	16,100	Monthly	3	193,200	84,400	4,500	.279	.023	100	0.25	99.75	Dept.
Jacksonville, Fla..	175,000	32,891	32,891	Monthly	5	394,692	78,938	8,400	.255	.021	100	0.1	99.9	Dept.
Little Rock, Ark...	114,280	18,909	18,909	Monthly	2	226,908	113,454	2,760	.145	.021	0	0	100	Dept.
Nashville, Tenn...	194,065	38,813	38,813	Mo. & qty.	4	158,852	39,713	7,200	.186	.045	29.6		Large majority	Dept. except over 1"
Norfolk, Va.....	173,000	32,751	29,928	Mo. & qty.	5	123,312	24,662	7,800	.261	.063	0	0	100	Consumer
Oklahoma City, Okla.....	205,000	38,930	38,500	Monthly	5	462,000	92,400	8,160	.212	.018	0	0.3	99.7	Dept.
Pasadena, Calif....	100,300	28,865	28,865	Monthly	4	346,380	86,595	6,480	.224	.018	0	0	100	Dept.
San Diego, Calif...	209,178	48,646	48,646	Monthly	8	583,656	72,969	12,672	.260	.021	0	0	100	Dept.*
Savannah, Ga.....	100,000	26,000	15,000	Monthly	8	180,000	22,500	9,600	.640	.053	5	0	100	Dept.
Shreveport, La....	108,303	19,631	19,631	Monthly	2	235,572	117,786	3,660	.186	.015	0	0.6	99.4	Dept.
Tampa, Fla.....	135,000	21,806	21,099	Monthly	5	253,188	50,637	6,600	.312	.026				Dept.
Total, 13 cities....	1,888,989	371,578	356,399		62	3,733,940	889,769	94,332						
Average.....	145,306.84	28,583	27,415	Mo. 85% Mo. & qty. 15%	4¾	287,226	68,444	$7,256	$.265	$.025	25	1	99	90% Dept.

* Costs are borne by the Department except when meters are damaged through fault of user.

TABLE 2—*Concluded*

CITIES	POPULATION INCLUDING SUBURBS	ACTIVE SERVICES	ACTIVE METERED SERVICES	METER READING PERIOD	NO. READERS	TOTAL READINGS PER YEAR	READINGS PER YEAR PER READER	ANNUAL SALARY READERS	ANNUAL READER COST PER METERED SERVICE	AVERAGE READER COST PER METER READING	PERCENTAGE OF CUSTOMER OWNED METERS	PERCENTAGE OF METERS IN BASEMENTS	PERCENTAGE OF METERS IN OUTSIDE BOXES	BEARER OF METER REPAIR COSTS
Combined Water and Electric or Gas Utilities														
Duluth, Minn.	101,065	19,310	19,310	Monthly	6	232,000	38,660	8,000	$.414	$.034	0	99.9	0.1	Dept.*
Fort Wayne, Ind.	118,410	29,483	29,483	Monthly	6½	358,116	55,000	10,764	.365	.030	0	97	3	Dept.*
Glendale, Calif.	85,257	21,124	21,124	Monthly	5½	253,488	48,000	9,580	.453	.038	0	0	100	Dept.
Kansas City, Kan.	122,000	25,592	28,178	Monthly	7	338,136	48,305	11,760	.417	.034	100	65	35	Dept.*
Lincoln, Neb.	82,000	21,810	19,902	Mo. & qty.	5	87,672	17,534	5,373	.270	.061	100	98	2	Consumer
Omaha, Neb.	223,844	53,774	53,170	Quarterly	10	214,996	21,499	13,200	.248	.061	98	70	30	To 1″ dept.*
Scranton, Pa.	255,650	44,568	36,993	Mo. & qty.	5	166,108	33,221	8,280	.224	.050	0	90	10	Dept.*
Knoxville, Tenn.	151,829	29,505	24,893	Monthly	5	298,716	59,743	6,051	.243	.020	0.5	0	100	Dept.
Long Beach, Calif.	169,300	34,993	34,993	Monthly	9	419,926	46,658	16,200	.463	.038	0	0	100	Dept.*
Total, 9 cities	1,309,355	284,159	268,046		58¾	2,369,158	368,620	$89,208						
Average	145,484	31,573	29,783	Mo. 67% Mo. & qty. 22% Qty. 11%	6½	263,240	40,958	$9,912	$.332	$.038	37.5	58	42	85% Dept.
Total, all cities	6,750,989	1,357,260	1,232,198		251¾	8,867,658	1,877,172	$393,346						
Average, all cities	143,638	28,878	26,217	Mo. 41% Qty. 19% Mo. & qty. 36% Mo. 4 mo. 2% Bi-mo. 2%	5⅓	188,674	39,940	8,369	$.319	$.044	30.5	54.5	45.5	88% Dept. 12% Consumer

bills are sent as in the other two groups, yet the total commercial department expense is nearly as high.

The percentage delinquency as reported bears no apparent relationship to whether penalty, discount or neither is applied. The use of stub and ledger systems is about evenly divided, and shows no strong governing influence in expense, although if nothing else were considered, the stub system might seem lower in cost. There are so many factors involved in all of the expense items that it is impossible to compare costs on the basis of one or two of them, as far as total commercial expense is concerned, and this is borne out by the fact that there is so little difference in average total commercial department expense among the three groups.

Meter Reading Costs

In compiling and comparing meter reading costs, no costs, except salaries of meter readers, as well as they could be ascertained, have been included. There are probably some errors in the tabulated figures, caused by wrong interpretation of the information given, which in some cases was indefinite. The average cost per meter reading is the best single index in the tabulation. It shows 4.4 cents as an average for 47 cities, the northern cities being 73 per cent higher, the southern cities 43 per cent lower and the cities of combined utilities 14 per cent lower than the average.

As shown, the average cost per meter reading is far lower in the South than in the North, as might have been assumed without collection of data, largely because of the greater accessibility of meters in that area, where 99 per cent are in tiles or pits adjacent to or in the sidewalks.

Salaries have no apparent relation to locality as far as North or South is concerned, although it might be said that they are usually higher in the Northeast and in California. The average salary of meter readers is $130 per month, ranging from $100 to $185.

There is considerable variation in actual duties of persons called meter readers. Sometimes they are also inspectors, collectors, and turn-on and turn-off men, but the comparison shown takes no account of this, as not enough information could be obtained to show it. When in one city a meter reader reads 118,000 meters per year, and in another about 6,000 meters per year, however, it is apparent that the first does nothing but read meters, and the second either does something else or has a great deal of free time to go fishing or hunting.

There are factors of efficiency and management, of course, and in some cases they are apparent in the tabulation. For example, in one city not included in the study, the meter readers averaged less than 100 meters per day, and they rather considered it their inalienable right to be finished with work, if not by noon, at least early in the afternoon. To accomplish this there was no hesitation about skips, estimated readings, and estimated bills. In the same city, a re-routing and reorganization was made, and the readers now average 200 meters per day, 5½ days a week, and skips and estimates are almost entirely eliminated. This change was affected in less than a year, in a city having at least 90 per cent of the meters in the basements. The same city is cutting its total commercial department expense in half in a little more than a year.

Interesting facts are that, in the 47 cities, meters are 30.5 per cent customer owned, 54.5 per cent in basements, and that 88 per cent of the departments bear the cost of meter repairs, except that about half of that 88 per cent charge the customer when damage is not due to normal use.

Many further conclusions or indications may be drawn from the tabulations by those particularly interested in this phase of water works operation. It is hoped that operators of the water companies mentioned, who were so obliging as to furnish the data for this report, may find some value in the material shown.

Survey of Meter Maintenance Practice

By A. P. Kuranz

ON THE following pages are reported the results of a survey of the meter maintenance practices of a group of municipalities, including Canadian cities of over 30,000 population and U. S. cities of between 100,000 and 200,000 population. In obtaining the information reported here, a questionnaire of 14 questions was forwarded to 21 Canadian and 47 U. S. cities. Replies were obtained from 16, or 76.2 per cent, of the Canadian, and from 36, or 76.6 per cent, of the U. S. cities, representing a composite return of 76.5 per cent of the questionnaires sent. In addition, several letters giving further information and encouragement, or explaining inability to reply, were received, all of which attests the live interest in the subject.

A study of the replies disclosed the fact that the records of the $\frac{3}{4}$-inch meter were generally included with those of the $\frac{5}{8}$-inch meter, so that no separate analysis was deemed necessary. Also, since the 1-inch meter was handled in much the same way as the $\frac{5}{8}$-inch size—the only real difference being that in 1-inch meters greater registration is permitted before the meters are removed—the three sizes were grouped, even in regard to their test requirements and repair costs. In short, there was not sufficient individual data to warrant repeating the analysis for each size, so the survey was made entirely on the basis of the $\frac{5}{8}$-inch disc type meter.

Following, then, are the various questions asked, together with the replies received and a brief discussion of the import of the information disclosed.

Question 1

Do you test all new meters before you put them into service? If you test new meters, what is the lowest flow in g.p.m. at which they are tested, and what accuracy do you demand?

A paper presented on June 26, 1941, at the Toronto Convention by A. P. Kuranz, Superintendent, Water Department, Waukesha, Wis.

Reply	*No. of Cities*
Test all meters	37
Test from 1 to 25 per cent	7
Do not test	8

Rate of Test, g.p.m.	*Accuracy Demanded, %*	*No. of Cities*
0.04	75	1
0.125 to .2	90– 98	4
0.250	90– 95	5
0.3–0.5	95–102	5
0.8–0.873	96–102	3
1.0–1.5	98–102	4
2.0–8.0	98–102	3
20.0	98–102	1
$\frac{1}{32}$-inch orifice	100	1
$\frac{1}{16}$-inch orifice	98–102	6
$\frac{1}{4}$-inch orifice	98–102	11

It will be seen that the majority of the cities test their meters when they are purchased or before they are placed in service, but that comparatively few test on the minimum requirements i.e. 0.25 g.p.m. Only 11 of the 52 cities test their meters on this flow or less, including one city testing on a $\frac{1}{32}$-inch orifice.

It appears that most water departments are concerned with proper registration in the class ranging from 0.3 to 1.5 g.p.m. From surveys available, however, it is known that approximately 12 to 15 per cent of the water is used at 0.25 g.p.m. or less and this should indicate that all meters be tested at the lower flows.

Answers to this question also indicate that a considerable number of plants still use the orifice method of testing, which, of course, has become obsolete and is no longer recommended for accurate testing.

Question 2

Do you remove meters after a certain amount of water has passed through them or do you set a definite period of time between removals?

When Removed	*No. of Cities*
After 4.5 to 5 yr.	11
After 6 to 7 yr.	5
After 10 to 20 yr.	4
By consumption, when stopped or slowing down, or upon complaint	15
By consumption (375,000 to 1,500,000 gal.) and time	11
No answer	6

These replies indicate a definite interest in the making of periodic inspections. The period varies greatly and is no doubt a function of the action of the individual waters upon the meters. Only in a few cases are the meters permitted to stop or slow down, and only in one case is the complaint used as the cause of removal. Eleven of the cities report the use of a combination of the time and consumption bases, apparently the most efficient way of handling the problem.

Question 3

Do you remove meters in a certain section of your city or do you follow the selective manner?

Method	*No. of Cities*
By section of city	8
Selective	33
Both	2
No answer	9

The fact that 33 of the 52 cities use a selective means of removal indicates further that the meter is not forgotten after its installation.

Question 4

How much time per meter is required to bring a meter into the shop?

Time Required, minutes	*No. of Cities*
10 to 20	8
22 to 28	6
30	10
40 to 50	8
60	9
90	1
No answer	10

These replies indicate some variation, but no doubt a more detailed survey which explained the steps involved in the removal of a meter would give more consistent results. Considering the fact that 41 of the 52 cities reported required times of from 10 min. to 1 hr., it seems evident that much depends upon the additional work necessary to restore service to the customer after the meter is removed.

Question 5

Do you test meters as they are brought into the shop for repairs?

If your answer is "yes," what is the lowest flow at which they are tested?

Answer	*No. of Cities*
Yes	37
On complaint or request	4
No	11
Rate of Flow	
0.14–0.2 g.p.m.	3
0.25 g.p.m.	8
0.3–1.0 g.p.m.	12
1.5–2.5 g.p.m.	2
5.0–8.0 g.p.m.	3
Full Flow	1
$\frac{1}{32}$-inch orifice	3
$\frac{1}{16}$-inch orifice	6
$\frac{1}{4}$-inch orifice	2
No report	12

This information is clear evidence of the interest of water works officials in the performance of meters under actual working conditions, both from the number of departments which test their meters and from the number of low flow tests given. Attention is again called to the use of the obsolete orifice method of testing.

Question 6

Do you take the meter apart completely? If you take only part of the meter apart, what part?

Method	*No. of Cities*
Complete disassembly (in 3 cases only on low test)	50
Partial disassembly	2

Question 7

What method of cleaning the disc chamber do you use?

Method	*No. of Cities*
Brush, scraper, emery cloth, sandpaper, powder (either alone or in combination)	31
Brush, scraper, emery cloth, acid (in combination)	10
Acid only	8
Powder and hot water	1
Water only	1
All methods	1

The answers to these last two questions bear out the fact that water departments are interested in keeping these "precision instruments"

in as nearly perfect condition as possible. Different waters, of course, affect the meters in different ways, some responding to certain kinds of treatment to which others are immune, but a survey as extensive as this, clearly indicates that mechanical means of removing deposits or corrosion are still preferred by most cities. Fine emery cloth, sandpaper and brush seem to be the chief implements used in removing foreign material. The small number using acid *only* indicates that departments have discovered that unless one is adept in the use of this material, more harm than good is done.

Question 8

Do you repair gear trains by putting in individual gears or by a complete new train?

Method	*No. of Cities*
Individual	30
Complete	8
Both	14

Since practically all meter companies now make all oil enclosed gear trains, some question has arisen concerning the maintenance of the gear train itself. It appears that most departments still believe that proper repairs can be made by replacing the worn gears with new ones instead of by a complete train. The mere fact that eight cities use nothing but a complete train in repairing the gear train and that fourteen use both methods, however, indicates that the time element involved in substituting individual gears for the worn ones is an important feature.

Question 9

Do you test meters after they are repaired? If your answer is "yes," what is the lowest flow in g.p.m. at which they are tested, and what accuracy do you demand?

Answer	*No. of Cities*
Yes	52
Lowest Flow Rate	
0.04-0.16 g.p.m.	2
0.25 g.p.m.	10
0.3-0.5 g.p.m.	5
0.75-1.0 g.p.m.	9
1.2-3.0 gp.m.	5
5 0-8.0 g.p.m.	3
20.0 g.p.m.	1

Continued

Lowest Flow Rate	*No. of Cities*
$\frac{1}{32}$-inch orifice	3
$\frac{1}{16}$-inch orifice	8
$\frac{1}{8}$-inch orifice	1
$\frac{1}{4}$-inch orifice	4
No flow reported	1

This is the one question which was answered in the affirmative by all 52 cities in the survey. The rates of flow reported are spread over a wide range. Upon analysis, however, it seems little different from the test requirements on new meters. The question might be asked at this time whether or not flows on repaired meters should be as exacting as those on new. If the flows on the new meters are analyzed and compared with those on repaired meters, one would be inclined to say that most departments feel that the repaired meters should be as near a new meter as possible in performance. Attention is again called to the fact that since considerable water is used from 0.25 g.p.m. to zero flow in the average home greater attention should be paid to the smaller flows.

Question 10

How much time per meter does it require to do the work covered in Questions 5, 6, 7, 8 and 9 (bringing the meter into the shop and testing it, taking the meter apart, cleaning the chambers, repairing the gear trains and testing it after repairs)?

Time, minutes	*No. of Cities*
30 to 55	9
60	10
70 to 90	13
120	4
150 to 210	6
No report	10

Here again, a considerable variation is shown, but again it can, no doubt, be explained by the different operations included and by the considerable time variation found in cleaning up the chambers as well as repairing the gear train.

Question 11

What is the cost of repair parts *only* based on a meter year basis? (Example: Cost of repair parts $2.80. Meter removed every 7 years would mean that $0.40 per meter per year is the actual cost of *repair parts only.*)

Cost	*No. of Cities*
$0.008	1
0.06–0.15	10
0.20–0.29	5
0.30	7
0.345–0.37	4
0.38 (including labor)	1
0.427–0.48	6
0.50–0.66	3
1.22	1
No cost reported	14

The fact that all types of meters are included in this survey may be the reason for the widespread difference, but it is believed the most important cause is the action of the water on the meter which, in turn, necessitates a difference in time period between removals for test and repairs.

Question 12

At what cost of repair in relation to the cost of a new meter do you feel it uneconomical to repair meters?

Cost of Repair, %	*No. of Cities*
30 to 40	3
50	20
55 to $66\frac{2}{3}$	4
75 to 90	7
Do not scrap	7
No answer	11

There seems to be quite a general accord on 50 per cent as the correct amount, most of the replies falling either on that point or between 30 and 66 per cent. No doubt the time required to make repairs is balanced against the cost of the repairs and the improved registration which results.

Question 13

When a meter is repaired, do you set the register back to "zero" or keep a continuous record of the total registration?

Method	*No. of Cities*
Continuous	20
Set back to zero	28
Both	3
No answer	1

The answers to this question seem to have little bearing on the efficiencies of the meter, but they do indicate that careful records are kept by most departments as to the performance of the individual units.

Question 14

What percentage of the water that you pump is accounted for through meters?

The answers to this question varied so greatly that only by referring to notes and letters attached could any comparison be made. Since cities are not all 100 per cent metered, no representative figures can be obtained. Many apparently have no master meters because with gravity systems they are little concerned with the supply. The cities which are 100 per cent metered and who have adopted a good meter maintenance practice plan, however, account for a large percentage of the water pumped. No figures will be given since a survey would have to be made on cities having all services metered.

Recommendations

In conclusion it should be pointed out that water utilities too often install meters and then neglect them, forgetting that they really are "precision instruments," the proper repair and testing of which will more than pay for the time and money spent. Too much stress cannot be placed upon the value of a proper meter maintenance program, outlined somewhat as follows:

1. Test all meters when purchased.
2. Remove them after a certain period of time or after a certain total consumption, or combination of both.
3. Test them when brought into the shop for repairs, keeping a record of these tests.
4. Repair them carefully, especially the chambers and gear trains, keeping a record of repair costs, both parts and labor.
5. Test them after repairs, requiring a high percentage of registration on a 0.25-g.p.m. flow.

Such a procedure will without a doubt result in distinct increases in water department revenues.

Water Rate Structures in Canada

By A. E. Berry and William Storrie

IN THE nine provinces of the Dominion of Canada is found a variety of conditions which have a bearing on water works administration and operation. Legislation on water works is provincial in scope rather than Dominion-wide. Other factors such as climate, sources of water, organization and personnel all may have an effect on rate structures.

In Canada, the provinces control the activities of the municipalities. Legislation is in force which empowers cities, towns, villages and townships to administer their own water works systems, and it is only through these enactments that a municipality is granted authority in this field. The effect of this provincial legislation is evident in the procedures adopted by water works authorities throughout the Dominion.

Since 1935, for instance, the Canadian Section of the American Water Works Association has issued to its members what is known as a "Waterworks Information Exchange." The underlying idea of this bulletin is to furnish members of the Section with information that may prove useful in permitting them to compare their own systems with others throughout the country. With this in view, questionnaires have been sent out, periodically, to the municipal authorities controlling water supply systems. The replies to these questionnaires have been tabulated under various headings, following which the information has been made available to the members in loose-leaf book form so as to be readily accessible. The subjects under which this information has been published are:

1. Water Purification
2. Finance, Accounting and Rates

A paper presented on June 24, 1941, at the Toronto Convention by A. E. Berry, Chief Sanitary Engineer, Ontario Department of Health, Toronto, and William Storrie, Consulting Engineer, Toronto.

3. Water Works Operation
4. Legislation and Court Decisions
5. Miscellaneous Data
6. Section Activities

The "Information Exchange" is now in its fourth volume, in which the material under each of these subjects is mimeographed on different-colored papers for ease of filing and reference.

There is in this activity a two-fold objective: (1) to prepare for the members a serviceable guide and statistical record in water works operation; and (2) to overcome duplication in the collection of data by individual water works officials. Through the co-operation of and suggestions offered by the members, information on various water works problems can thus be exchanged. Members are asked to send in their suggestions for material to be collected, as well as their criticism and comments at all times.

There is now in operation, in Canada, approximately 1,300 public or municipal water works systems distributed, by provinces, as follows: British Columbia, 128; Alberta, 40; Saskatchewan, 33; Manitoba, 14; Ontario, 290; Quebec, 691; New Brunswick, 28; Nova Scotia, 34; and Prince Edward Island, 2. Many of these are, of course, quite small. The material presented in this paper is made available chiefly through the data collected for the "Information Exchange," which, while it does not in most cases, cover all the water works systems in Canada, does include those which have members in the A.W.W.A., and which may, therefore, be considered as representative of the best practice in the country. Discussion is under two sections, one dealing with domestic rates, and the other with municipal services and fire protection charges.

Part 1. Domestic Rates

Since water rates are unquestionably influenced by the type of organization responsible for the administration it will be desirable to note of what this consists in Canada. A recent survey of these systems reveals that they are almost exclusively publicly owned. The actual supervision and administration of these come generally under either a utilities commission or a committee of the municipal council, Ontario having a much higher proportion of utilities commissions than do the other provinces. Most of both these types of administrative bodies are charged also with the administration of electric systems.

The charges for domestic water supplies in Canada are divided into the usual two groups—flat rates and metered rates. The details for making these levies vary greatly under both types, and much of this practice appears to be based on what is done elsewhere rather than on the actual cost of service.

Use of Meters

The extent to which meters are used in the larger population centers is shown in Table 1. In this table metering of services is broken down into its use for residences and for industrial or commercial purposes. Comparison of the number metered with the percentages of the water metered and the percentage of the revenue secured from metered services is of particular interest. It will be apparent from these data that even in the cities of the Dominion, the proportion of residential services metered is on the whole quite low. Commercial services on the other hand, are practically all metered, so a much higher proportion of the total water is metered and a higher revenue is derived from this source than might be expected from a study of the data on domestic supplies.

The information in the table refers only to cities; a review of the towns and smaller centers shows a still lower number of metered supplies. The wider use of metering in western Canada may be explained by the fact that installation of the systems is more recent and that water supplies are less abundant there than, for instance, in Ontario. Such is the present situation in Canada, despite the very evident trend in recent years towards the use of meters and the wider recognition of this method as the most equitable for the consumer and for the municipality. In the summary of water works systems reported, it is shown that 61 per cent of the municipalities had less than 50 per cent of their residential services metered. If other non-member municipalities were included, this figure would, of course, be considerably higher.

Flat Rates

The methods of determining flat rate charges for water vary a good deal in these same centers. Many follow the same general principle of levying specific charges for such fixtures as sink or tap, bath, basin, toilet and laundry tub. A rate is set for the first of each of these in a residence, and another for additional fixtures of the same kind. There appears to be little relationship between the charges

made for the first of these units and the extra ones. It varies all the way from the same amount to a third or less. This discrepancy

TABLE 1

Use of Meters in Large Population Centers of Canada

MUNICIPALITY	PERCENTAGE OF SERVICES METERED			PERCENTAGE MEASURED BY METERS	
	Residential	Industrial or Commercial	Total	Of Water	Of Revenue
Belleville	1	82	6.4	—	—
Brantford	75	100	78	—	—
Calgary	11	90	14	—	—
Chatham	100	100	100	100	100
Galt	97.5	100	97.5	95	95
Guelph	(few)	100	0.036	—	—
Hamilton	—	100	11	36.3	49
Kingston	1	100	10	17.5	40
Kitchener	99.5	100	99.5	75 80	90
London	100	100	100	80	92.4
Montreal	0	100	3	—	25
Niagara Falls	0	95	3	39.8	40.1
Oshawa	73	77	80	65	—
Ottawa	0	100	—	33.8	21.5
Peterborough	0	100	4.5	20	26
Port Arthur	20	100	22	—	—
Regina	89	100	97	65 70	96
St. Catharines	2.5	100	0.66	44	43
St. John	0	100	4.5	28.2	18
St. Thomas	65	100	63	—	—
Sarnia	0	100	3.5	21.8	30.8
Stratford	94	88+	93	—	94
Toronto	—	—	5.38	41.37	37.81
Vancouver	4.1	100	15	33	5.26
Victoria	100	100	100	100	100
Welland	0	99.9	—	—	—
Winnipeg	99	99	99	70	95
Woodstock	0	100	5	39	41
Averages	36.9	93.9	43.4	36.0	37.1

does not seem so important, however, when it is realized that flat rates cannot be expected to be equitable in any event.

Several of the municipalities base their flat rates on the number of rooms in the house as well as on the number of fixtures, and some

on the number of consumers. These bases necessitate either a frequent check on the premises and the number of occupants or result in inequitable charges.

Assessment of the premises as a means of determining the water rate is used in a substantial proportion of the municipalities. Hamilton, Kingston and Ottawa in Ontario, all adhere to this practice. A somewhat similar procedure appears to be prevalent in the Province of Quebec, but with a modification to the assessed annual rental of the property. Montreal employs such a method.

Rates which are based on assessment have the advantage of simplicity as compared with fixture rates, and they can be checked readily for any change without the necessity of a canvass of the premises. It can scarcely be expected, however, that assessment values will form any accurate index of the amount of water likely to be used on the premises.

The charges made for the first tap or kitchen sink, in different municipalities vary from $1.50 to $15.00, the average being about $6.00. The first bath is about $3.00, the first basin, about $1.50 and the first toilet fixture, about $4.00.

A separate scale of charges is set up for lawns and gardens. Most of these are graded according to the area involved, others make one charge irrespective of size. The rates are increased where sprinklers are used.

Building rates are classified generally on the bases of number of bricks, amount of concrete, stone or plastering, and similar units.

For commercial and business purposes, flat rates include a great number of different methods, involving the number of employees, the business fixtures used, the number of machines, etc., all of which are somewhat complicated and difficult of comparison with other rates. Where the assessment is used, the procedure, at least, is simplified.

A review of the methods used for the adjustment of water charges on a flat rate makes it apparent that there is no close uniformity of methods as between municipalities, and as between the different services supplied. It becomes obvious that this method cannot be expected to be equitable where the amount of water used or the service rendered should be the criterion. That the trend in Canada is toward metering is a further indication of this defect. The fact that metered rates are not always popular with the consumer, especially at the outset, however, has retarded the progress of that trend.

Metered Rates

In those centers where metered water rates are in force, the situation is much more equitable. Provision is made for the rent of the meter either as a separate charge, or included in the water bill as a part of the minimum charge. Sliding rates, varying with the amount of water consumed during the billing period, are in general use. There is a complete lack of uniformity, however, in regard to the division lines between changes in the scale of rates.

In those cities in which the domestic supplies are metered to almost 100 per cent there appears to be a fairly even division between the practice of making a special charge for meter rental and that of including it in the minimum charge. It would seem that the latter practice is less likely to cause criticism and is more acceptable in general to the consumer. For the larger industrial or commercial consumer, however, this is less likely to be a factor of importance in public relations.

Billing periods for either the flat rate or metered rate show little uniformity. They vary from one to six months, with some being twelve months. Of the water utilities studied, 62 per cent use a 3-month billing period, 17 per cent a 2-month period, and 9 per cent a 1-month period. Shorter periods appear to be more popular for large consumers than for domestic supplies, and commercial meters are read monthly in many places. The cost of meter reading approximates 25 cents per meter per year, with variations depending on the number of readings and other factors.

The cost of water to the consumer is not always the amount shown on his water bill. In Canadian municipalities, a number of other charges of an indirect nature are included. These are paid in taxes under different items. Some taxes include a part of the capital costs as well as fire protection and local improvement rates on mains.

A survey has been made of water bills paid in Canadian municipalities for a specified type of residence—a 5-room house with four occupants, an assessment of $2,000 and a frontage of 45 ft. These figures were compiled for both metered and flat rate consumers. For metered premises the amount of water included was 25,000 gal.* per yr. The average costs per year, including all items, were $16.00 for the flat rate property and $14.45 for the metered consumer.

* All values in gallons refer to Imperial gallons. (1 Imperial gallon = 1.2 U. S. gallons.)

The average costs for water works systems in Canada has been computed to be $4.83 per capita per year, with debt charges amounting to 44% of this total, or $2.14. These costs must serve as the basis for the rates to the consumers. Similarly, the charges for water supplied have generally been between 8 and 15 cents, with an average for a selected group at 13.75 cents per 1,000 gal. The two largest cities of the Dominion showed annual costs of $4.02 and $4.90, per capita with the cost of water per 1,000 gal. being the same, 11.7 cents, in each case.

Similar capital costs for water filtration plants have been given as $11.35 per capita for gravity plants, and the average cost per million gallons of designed capacity for these plants was $67,965. Water consumption for Canadian municipalities, in 1939, was 109 g.p.d. per capita.

In providing water services for apartments and multiple dwellings, the more generally accepted practice has been to use one meter for the building and make the owner responsible for the account—a practice which is always more convenient for the water department. In Ontario the owner of rented property must make available for the tenant a satisfactory water supply.

Part 2. Municipal Services and Fire Protection Charges

Public water supplies have a most important duty to perform in furnishing fire protection service. This service can be divided into two classes:

1. The "public service," by which is meant the furnishing of an abundant supply of water at adequate pressure through hydrants attached to the distribution system.

2. The "private service," by which water is supplied under satisfactory conditions as to quantity and pressure through hydrants or a sprinkler system connected with industrial or other large establishments.

The Canadian practice in determining the basis of comparison for public fire protection service charges is wide and varied with little or no attention being given to ascertaining what such service actually costs. What the traffic will bear has long been the controlling factor. Through the "Information Exchange," statistics have been prepared covering the practice in 103 municipalities in Canada in 1935. As will be seen, the charges show a wide variation, such as, on a hydrant rental basis, varying all the way from no charge up to

$231.00, with an average of $40.42 per hydrant per annum. Even on a per capita basis, the charge varies from zero to $5.96 per capita per annum, with an average of $0.46 per capita. Table 2 shows the general situation as far as fire protection charges are concerned. Table 3 gives a general summary of the basis of charge in eight of the nine provinces. Here again wide variations, even in the same province, may be noted.

To bring up to date some of the information contained in these tables, a questionnaire was recently sent out to the various municipalities. Replies were received from 109, of which 91 were in Ontario. From the replies received the following information was extracted.

TABLE 2

Data on Fire Protection Practices of 103 Canadian Municipalities in 1935

ITEM	AVERAGE	MINIMUM	MAXIMUM
Charges:			
Per capita	$0.46	$0.00	$5.96
Per hydrant	40.42	0.00	231.00
Per mile of mains	307.00	0.00	2,511.00
Per inch-foot unit	0.00723	0.00	0.0817
Part of operating expense (excluding cost of treatment) represented by charges, %	11.9	0.0	74.5
Mill rate of charges on total taxable assessment, *mills*	—	0.0	11.65
Hydrants:			
Number per 1,000 population	7.9	3.1	55.2
Number per mile of mains	3.9	3.0	22.8
Number of inch-foot units per hydrant	5,230	1,460	11,170

Variations in Fire Protection Charges

1. Public utilities commissions control 70 of the systems while municipal councils control 38, *only 1* being owned by a private company.

2. Of the 91 Ontario municipalities reporting, 79 derive revenue for fire protection purposes, 65 of these, on a hydrant rental basis.

3. The average yearly rental per hydrant in Ontario is $38.00, ranging from $1.75 to $100.00.

4. The average revenue for fire protection purposes in Ontario is 14.6 per cent of the total revenue received, ranging from 0.06 to 43 per cent.

TABLE 3

Data on Fire Protection Practices of 103 Canadian Municipalities, by Provinces, in 1935*

ITEM	BRITISH COLUMBIA	ALBERTA	SASKATCHEWAN	MANITOBA	ONTARIO	QUEBEC	NEW BRUNSWICK	PRINCE EDWARD ISLAND
Number of Municipalities reporting	2	1	2	1	85	10	1	1
Charges:								
Per capita								
Min.	$0.00	$0.54	$0.93	$0.74	$0.00	$0.00	$1.30	$0.00
Max.	0.75		1.41		5.96	0.00		
Per hydrant								
Min.	0.00	40.00	54.25	57.63	0.00	0.00	68.00	0.00
Max.	32.00		75.00		231.00	0.00		
Per mile of mains								
Min.	0.00	199.30	604.00	520.00	0.00	0.00	348.00	0.00
Max.	181.00		640.00		2,511.00	0.00		
Part of operating expense (excluding cost of treatment) represented by charges, %								
Min.	0.0	7.1	16.1	15.3	0.0	0.0	14.1	0.0
Max.	8.8		31.9		74.5	0.0		
Mill rate of charges on total taxable assessment, *mills*								
Min.	0.0	0.74	—	0.66	0.0	0.0	—	0.0
Max.	0.90		1.10		11.65	0.0		
Hydrants:								
Per 1,000 population								
Min.	15.7	13.6	12.4	12.8	3.1	5.1	19.1	7.9
Max.	23.4		26.0		55.2	12.6		
Per mile of mains								
Min.	5.7	5.0	8.56	9.0	3.0	6.36	5.1	3.9
Max.	5.9		11.1		22.8	10.9		
Cost of operation (including fixed charges less treatment costs) per capita								
Min.	$4.70	$7.70	$5.30	$4.83	$1.40	$0.85	$9.20	$2.09
Max.	8.47		5.76		11.06	6.23		

* No report from Nova Scotia.

5. The revenue derived from fire protection, in 16 selected municipalities in Ontario, amounted to $238,951, but water works systems paid to the same municipalities, for the reduction of the general tax rate, the sum of $637,551 or $398,600 more than was received.

6. Municipally owned water works systems in almost every case do not pay municipal taxes. In Ontario, all publicly owned utilities are exempt from municipal taxes.

7. In Calgary, Alta. (population, 85,726), a tax contribution of 5 per cent of the total revenue is paid by the water works system in lieu of municipal taxes. In addition to this a large yearly surplus from the operation of the system is turned over to the city. The amount of the tax bears no relation to the assessed value of the water works system but is purely an arbitrary figure set by the city council. Saskatoon, Sask., provides for a similar tax, amounting to approximately 5 per cent of the revenue.

8. In Windsor, Ont., (population, 116,635), a hydrant rental of $60 per annum and 1.5 mills on the assessed value of the property is charged for fire protection, in addition to a rate of 6.3 cents per foot frontage per annum on all vacant property owned by the city. These items account for 22.6 per cent of the total revenue.

9. At Peterboro, Ont., (population, 24,530), an annual sum equal to one-third of the cost of operation (excluding the cost of water purification) is charged for fire protection purposes. This sum approximates 15 per cent of the total revenue.

10. At Brantford, Ont., (population 31,135), the charge consists of the annual debt costs on "fire protection equipment," plus 10 per cent of the total operating costs. The total charge thus amounts to about 12 per cent of the total revenue.

11. In Teck Township, Ont., (population, 18,000), a charge of 5.48 mills is included in the tax rate to cover debenture debt. No other revenue is derived for fire protection purposes.

12. At St. Thomas, Ont., (population, 16,817), an annual hydrant rental of $10 is charged, together with a rate of $1\frac{1}{4}$ cents per inch-foot of distribution mains. These charges amount to 15.9 per cent of the total revenue.

13. At Winnipeg, Man., (population, 224,252), an annual charge of $30 per hydrant and a rate of 4 cents per foot frontage annually combine to produce a revenue of about 15 per cent of the total revenue received.

14. At Three Rivers, Que., (population, 45,000), the estimated

amount of water used for fire protection is charged for at the rate of 20 cents per 1,000 gal., plus a rate of 50 cents per annum for each $100 assessed value of the property.

15. In other municipalities the annual charge for fire protection is made up of a rate per hydrant together with a fixed sum, which varies depending on the size of the municipality.

16. It is apparent that, in almost every case, the municipalities are not charged enough for fire protection. Some of the largest cities derive no revenue whatever for such services.

Disposal of Surplus Funds

When, in many of the smaller municipalities in Ontario, a water supply is installed for the first time, the usual practice is for the municipality to pay a portion or all of the debt charges out of its general funds. When a surplus is created after paying all operating, maintenance and debt charges, either the rates to the consumers must be reduced or the surplus paid over to the treasurer of the municipality to be applied annually to the reduction or extinguishment of the rates required to be levied under any by-law for the issue of debentures of the municipality for the construction, extension, or improvement of the works (Sec. 31, Public Utilities Act, Ch. 286).

Under Sec. 44 of the same act, "The revenues, after deducting disbursements, shall, quarterly or oftener, if the council so directs, be paid over to the treasurer of the municipality, and shall be, by him, placed to the credit of the account of the public utility work, and, if not required for the purpose of the work, shall form part of the general funds of the corporation."

From returns submitted by various municipalities it is to be noted that in many systems large surpluses, which far exceed the revenue derived for fire protection purposes, have been created. A reading of the Act leaves room for doubt as to whether a municipality is justified in using such surpluses for any purpose other than the water works system so long as any outstanding debt exists. It is, therefore, hoped that before long the legislation in Ontario will be cleared up so as to determine definitely the nature of the disposal of these surplus funds.

In Ontario, the City of St. Catharines has a special act which enables the utilities commission to apply any surplus toward the redemption, before maturity, of any of the outstanding water works debentures.

Special Rates and Free Water

Where hydrants are installed on private property the consumer is invariably called upon to pay the total cost of installing the service from the water main up to the hydrant. In few municipalities is any annual charge made for such hydrants. Where such charges do exist, however, they vary all the way from $2 to $50 per hydrant per annum. These charges vary on the basis of the size of the connection and the type of hydrant.

In general the consumer is called upon to pay the cost of the sprinkler connection from the main, but rarely is an annual charge made for the use of sprinklers. The annual charge for a sprinkler connection varies from $15 to $75 per annum, and, in other cases, a rate per sprinkler head varying from 3 cents to 10 cents is charged. Such charges are sometimes on a graded scale, based on the number of heads in service.

In general, throughout Canada, the policy of making no charge for water used for municipal purposes, such as street sprinkling, sewer flushing, public parks, municipal and public buildings, prevails. The chief exception to this is the use of water for public schools, where the general practice is to meter and charge at the regular water rates. In certain municipalities, flat rate charges are made for street watering, flushing sewers, public parks and hospitals, but the amount charged is often a nominal sum in no way commensurate with the amount of water used.

For sewer flushing one municipality pays 50 cents per manhole per annum. Another municipality charges $6 per room in each school. One municipality charges $10 per month for each school. A municipality with a population of 4,280 has a revenue from schools of $358, from horse troughs, $100 and from the Town Hall, $29.70 per annum.

From the above it will be seen there is a wide variation in the revenue for water supplied for municipal purposes. The usual argument, that since the water works system pays no taxes, water used for municipal purposes should be supplied free of charge is the basis for much of the inadequacy of charges.

Need for Grading Schedule

Canada has no grading schedule similar to the one used by most of the Fire Insurance Rating Organizations in the United States. Fire protection reports are issued from time to time by the Canadian

Underwriters' Association, following a physical examination of the water works system, fire department, fire alarm system, police protection, building by-laws and the fire record over a period of years, but Canadian municipalities are under a distinct handicap in that no satisfactory yard-stick exists that would be a guide for measuring the relative standing of various municipalities in this respect. If such a rate schedule were established, it would enable those operating the system to ascertain definitely not only the local rating, but wherein and to what extent their system was deficient. The underwriters' reports give detailed information on where the system is deficient, but the difficulty of the operating board is to ascertain definitely the relative value to be placed on such deficiencies.

There is great need throughout Canada for a greater understanding by the authorities of water works systems of the relationship between the water works industry and the fire insurance business. The average water works engineer has little or no knowledge of how the fire insurance rate has been established. An understandable knowledge of the requirements set up by the underwriters would show the weaknesses of each system and would thereby be an incentive for the reduction of grading deficiencies to a minimum. With such a grading schedule the water works engineer would be in a much better position to approach his superiors with plans for improving the system. The deficiency schedule might, for instance, clearly indicate that the sum of $50,000 could more effectively be spent on the fire department than on the water works system.

It is further suggested that closer co-operation should exist between the underwriters and the water works engineers. In the present procedure, tests are made, the system sized up, and a report issued to the municipality indicating the defects, and there the matter invariably ends. The water works engineers should be in a position to have the underwriters appear before his board to back up any recommendations he may make, covering the deficiencies reported by the underwriters.

Some business-like means of determining what fire protection actually costs in a municipality is a pressing need in Canada. Water works systems should be run on sound business lines and the consumers should benefit directly from the use of the system. Whether it be from the quantity of water actually used for domestic and industrial purposes or from fire protection, the charges should be adequate and fair for the service rendered and the benefits derived.

Report of the Joint Research Committee on Boiler Feedwater Studies

By R. C. Bardwell

BEFORE presenting the formal report covering the current activities of the Joint Research Committee on Boiler Feedwater Studies, it is considered advisable to review, briefly, the developments and progress made by this Committee since it was organized under the auspices of the American Water Works Association in 1924.

At the suggestion of the late George W. Fuller, during the A.W.W.A. Convention at New York in May, 1924, a group of 36 men representing the A.W.W.A., the National Electric Light Association and the American Railway Engineering Association, held a meeting under the chairmanship of Sheppard T. Powell to discuss the advisability of forming a joint research committee on boiler feedwater studies to consider the allied problems in this work from the viewpoint of the water producer and consumer. These studies were to include the water used for steam purposes in power plants and on railroads. The organization of such a committee was definitely approved and its activities have continued from that date. Other technical associations were likewise interested and offer of joint sponsorship was later received from the American Society of Mechanical Engineers, the Boiler Manufacturers Association and the American Society for Testing Materials. The National Electric Light Association was succeeded by the Edison Electric Institute, and, with this change, the activities of the Joint Committee are still being sponsored by these six national associations.

The organization of the Joint Committee under the chairmanship of Sheppard T. Powell, consisted of an advisory or executive committee, composed of two members from each of the sponsoring societies, and 9-sub-committees composed of 57 members selected from

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the associations on the basis of their interest in the particular problems. The sub-committees, by number, encompass the following subjects:

1. Sedimentation with and without chemicals, pressure and gravity filters and deconcentrators and continuous blowdown apparatus
2. Water softened by chemicals (external treatment)
3. Zeolite softeners, internal treatment, priming and framing and electrolytic scale prevention
4. Surface condensers, evaporators and de-aerators
5. Corrosion of boilers and the effect of treated water in accelerating or relieving these troubles
6. Embrittlement of metals
7. Municipal water supply in relation to boiler use
8. Standardization of water analysis
9. Bibliography

The first work of these sub-committees was to review the studies which had been made on the respective subjects and to prepare an outline for future investigation. Programs were sponsored by the Committee before the A.W.W.A. Convention at Buffalo in June, 1926, and before the American Society of Mechanical Engineers' annual meeting at New York in December, 1927. Further programs for sessions at annual meetings of the sponsoring associations have been handled by the Committee and progress reports on the studies under investigation have been presented from time to time.

It was realized by the Executive Committee, soon after the movement was started, that real progress could be made only through comprehensive paid research. Funds were solicited to finance the costs for carrying out a research program on what were considered the most important problems:

1. The corrosion of boilers and auxiliary equipment
2. Priming and foaming of boiler water
3. The embrittlement of boiler steel

Arrangements were made for the treasurer of the American Society of Mechanical Engineers to be custodian of these research funds. Various industries and power companies made contributions to a total of about $4,000. This amount was not considered sufficiently large to justify starting any extensive research program, and the depression, which began in 1929, caused a definite postponement of the contemplated large contributions from the American Railroad Association and the National Electric Light Association.

Meanwhile, in 1931, a portion of the research fund was allocated to assist Professor C. W. Foulk at Ohio State University in carrying out research work on the priming and foaming in boilers, and another portion for research work, under Professor A. H. White at the University of Michigan, for determining the most satisfactory methods for analyzing carbonate, hydroxide, sulfate and phosphate in boiler waters. Preliminary reports on these subjects were presented at the annual meeting of the American Society of Mechanical Engineers at New York in December, 1931, and final reports, in 1935. With the assistance of funds from the Engineering Foundation, it was possible to carry out research work, under Professor White, on the development of a referee method for determining small amounts of dissolved oxygen. This was reported to the annual meeting of the American Society for Testing Materials in 1937.

The most extensive research coming under the Joint Committee has been handled by Sub-Committee No. 6 on the Embrittlement of Metals, under the chairmanship of J. H. Walker. In 1932, a number of industries, utility companies, and insurance companies made substantial contributions toward carrying out an investigation on the fundamental causes of this phenomenon. Through the co-operation of the Bureau of Mines, facilities and directing personnel were afforded for the research work with the funds thus provided.

During the first few years of the investigation, the lack of definite information on the subject, as well as misconception of many facts which had been taken for granted, were clearly demonstrated. The interest in the investigation has increased, particularly in connection with research work to determine the most practical means for overcoming the trouble. To date the contributions and expenditures have reached the sum of approximately $60,000, toward which the Association of American Railroads has been one of the principal contributors. The information developed has been of tremendous importance, and although the work cannot be said to be fully completed, large savings are already being made where advantage is being taken of the information that has been made available.

At the Cincinnati Convention of the A.W.W.A. in May, 1935, Sheppard T. Powell, who had served as Chairman of the Committee since its formation, found it necessary to relinquish his position due to the pressure of other duties. C. H. Fellows, of the Detroit Edison Co., was then elected Chairman, R. C. Bardwell, of The Chesapeake and Ohio Railway, Vice-Chairman, and J. B. Romer of Babcock & Wilcox Co., Secretary. These officers, in co-operation with an

executive committee, composed of two representatives from each of the six sponsoring societies, are still directing the work of the Committee.

The present members of the Executive Committee are:

American Boiler Manufacturers Association—G. E. TATE, P. B. PLACE
American Railway Engineering Association—R. E. COUGHLAN, B. W. DEGEER
American Society of Mechanical Engineers—A. G. CHRISTIE, A. E. WHITE
American Society for Testing Material—MAX HECHT, F. N. SPELLER
American Water Works Association—H. E. JORDAN, S. E. POWELL
Edison Electric Institute—M. F. STACK, E. H. TENNEY

The officers of the various sub-committees are as follows:

No. 1, Coagulation and Sedimentation—A. P. BLACK, *Chairman*
No. 2, Organic Chemicals for Internal Water Treatment—*Inactive at present*
No. 3, Foaming and Priming—*Inactive at present*
No. 4, Electrolytic Prevention of Scale and Corrosion—*Inactive at present*
No. 5, Corrosion—F. N. SPELLER, *Chairman*
No. 6, Effect of Solution Composition on the Cracking of Boiler Metal—J. H. WALKER, *Chairman*
No. 7, Municipal Water Supplies in Relation to Industrial Use—*Inactive at present*
No. 8, Standardization of Water Analysis Methods—A. H. WHITE, *Chairman*
No. 9, Patents—*Discontinued*

Committee Activities for the Past Year

The following is a formal report of the Joint Committee on Boiler Feedwater Research for the year 1941:

During the past year the Joint Research Committee on Boiler Feedwater Studies has continued its activities along the lines followed during the several preceding years, and, on behalf of the committee membership, the officers take pleasure at this time in presenting their annual report to the six sponsor societies of this committee.

During the past year the activities of the committee comprised:

1. The sponsoring of a Boiler Feedwater Session, in connection with the Spring Meeting of the A.S.M.E. held in Worcester, Mass., in May, 1940. At this meeting, written discussion was presented of the paper entitled "Attack on Steel in High-Capacity Boilers as a Result of Overheating Due to Steam Blanketing" by E. P. Partridge and R. E. Hall. This paper had been presented at the Spring meeting in New Orleans in 1939. At the Worcester meeting, several papers written in discussion of the Partridge and Hall paper were presented and later reprinted in A.S.M.E. publications. At this meeting, Mr. Guerney of Gulf States Utility Co. presented a paper on steam purity that was prepared jointly by himself and Dr. Schwartz.

2. In connection with the meeting of the Mechanical Division of the Association of American Railroads held in Chicago in June, 1940, Dr. Schroeder presented a summary of the work on "Caustic Embrittlement," that is being carried out under the auspices of the Committee at the Eastern Experiment Station of the United States Bureau of Mines (this report was later reprinted by the Mechanical Division of the Association of American Railroads, V. R. Hawthorne, 59 E. Van Buren St., Chicago).

3. A Boiler Feedwater Session was sponsored in connection with the annual meeting of the American Society of Mechanical Engineers held the first week in December in New York. A paper emphasizing the problems created by the presence of silica in boiler feedwater and boiler water was presented, followed by two papers discussing the latest processes by which silica can be removed from boiler feedwaters. Reprints of these papers can be obtained by addressing requests for them to the Chairman of the Joint Research Committee on Boiler Feedwater Studies.

The principal research activities of the Committee during the past year have been confined to the continued study of the problem of caustic embrittlement as carried on under the auspices of Sub-Committee No. 6 at the Bureau of Mines, Eastern Experiment Station at College Park, Md. J. H. Walker, Chairman reports as follows concerning this work:

"The extensive use of the embrittlement detector attached to operating boilers is serving to cover a wide variety of operating conditions, and its use in other laboratories not only is furthering the study of the effects of solution composition on steel specimens, but is also providing checks on our own laboratory operation. In use at present are 30 units in the Bureau of Mines and 54 in other laboratories.

"There has been close co-operation with the National Aluminate Corp. of Chicago. Dr. E. G. Johnson of the National Aluminate Staff spent several weeks at the Bureau of Mines acquiring a background of the embrittlement problem and the technique of running embrittlement detector tests. Dr. Johnson now has 34 detector units in which two specimens are clamped on opposite sides of the detector blocks. It is thus possible to run simultaneous tests, either checks tests on the same type of steel or simultaneous testing of plain carbon and alloy steels with the same water. This organization is primarily interested in developing the use of organic inhibitors for railroad operation.

"The Dearborn Chemical Co., also of Chicago, has likewise sent members of its staff to the Bureau for the purpose of observing construction and operation of the detectors. This company now has about 11 units of its own in which it is making a study of the effectiveness of organic inhibitors primarily for railroad operation. It is also making a careful study of rates of leakage and their effect on the incidence of cracking.

"Hall Laboratories, Inc., of Pittsburgh, is setting up several units for laboratory investigation, but the primary efforts of this organization have been concerned with the direct attachment of the detector to operating boilers. There are over 100 installations of this type throughout the country and a large mass of data is being collected. In addition to the operating data of the units themselves, at least three water analyses are made during each test and whenever questionable results are obtained or an unusual boiler water is tested, a sample is shipped in an uncoated steel drum to the Bureau of Mines for testing."

With further reference to the work of Sub-Committee No. 6, it may be appropriately stated that the present funds available to the committee are expected to be expended by the end of the year 1941, and consideration is being given to instituting new research work, probably on silica, by which the research staff at the Bureau may be continued to be employed on boiler feedwater projects. It is to be noted in connection with the work of this sub-committee that the Bureau of Mines has to a large extent underwritten the cost of much of this research work during the last two years. The officers of the Joint Research Committee desire to take this opportunity publicly to express their appreciation for this assistance.

The Sub-Committee No. 9 on Patents issued its fourth progress report that covers all patents for the year 1939 on water treating and

water-treating equipment. In an effort to determine how useful the report of this sub-committee has been to industry, the Committee authorized the printing and sale of this current report. Individual copies can be procured, at a nominal cost, from the secretaries of the six sponsoring societies, although the principal point of distribution is the A.S.M.E. headquarters. At its executive committee meeting held in December, 1940, the Joint Research Committee decided that further elaborate efforts on the part of Sub-Committee No. 9 on Patents would be discontinued, inasmuch as there was not enough apparent interest on the part of industry to justify this continued effort. The Executive Committee regretted exceedingly that this action was necessary.

At the meeting of the executive committee, consideration was given possible programs under the sponsorship of the Joint Research Committee at the annual meeting of the American Society for Testing Materials, as well as at another meeting to be held in connection with that of the Mechanical Division of the Association of American Railroads. It was later found, however, that due to conflicts and the nature of the programs of these organizations, it was more expedient to drop any consideration of a separate boiler feedwater session at the meetings. In lieu of this, officers of the Joint Research Committee will present formal reports to the sponsoring societies and discuss, personally, details of the work of the Committee.

Current plans call for a symposium on the subject of caustic embrittlement and intercrystalline corrosion of boiler steel to be held in connection with the annual meeting of the American Society of Mechanical Engineers in December, 1941. At this symposium it is the intent that the individual students of the problem will present such data as may be available as a result of their studies and thus make available for general discussion what may be considered to be a true cross-section of the industry's experience with the problem. There is in preparation, at the present time, a summary of the entire research program of Sub-Committee No. 6, relating to embrittlement, which it is planned will be issued as a Bureau of Mines Bulletin under the joint sponsorship of the Bureau of Mines and the Joint Research Committee. It is expected that this will be available shortly after the first of the year.

The officers of the Joint Research Committee on Boiler Feedwater Studies would like to take this opportunity to express their keen appreciation of the valuable assistance and advice given them from time to time by the members and officers of the sponsoring societies.

Studies in Corrosion Control

By H. P. Stockwell, Jr.

THE coagulation of colored raw water supplies of the type so prevalent in some parts of Canada usually results in a filter effluent of slightly acidic, and therefore quite corrosive, properties. At Ottawa, Ont., for instance, coagulation with alum, to remove color, results in an effluent pH of between 5.5 and 6.0, a condition which demands correction. The addition of lime to give a final pH slightly above the calcium carbonate solubility equilibrium value is of some value in reducing corrosive attack but total elimination of corrosion is not so obtained. Further progress toward that necessary goal must, then, be effected by the accumulation of quantitative data concerning the effect on common pipe materials of the various treatment methods applied to the water supply concerned.

In addition to the initial cost of the pipe, the water consumer is interested in the degree of corrosion and the physical characteristics of the corrosion product, both of which influence the amount of "red water" encountered at the tap. The consumer is also interested in the effective life of the pipe, which, because of pitting in certain instances, is not necessarily a function of total corrosion. The tests described in this paper have been carried out to throw some light on the problem of corrosion control in treating the Ottawa municipal supply, to evaluate the relative resistances of the various metals used for household piping, and to compare the present supply with the unfiltered colored river water as pumped to the city in former years.

Corrosion studies may be carried out either under actual service conditions, as by inserting specimens in household water lines, or in the laboratory, where conditions can be more carefully controlled. If many specimens are to be studied, as in this instance where 600

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pieces were under test, the laboratory method is the more convenient. Conditions can be regulated to conform with those existing in the average household water system and the progress of corrosion may be measured in any one of several ways.

Testing Methods Available

The testing method may involve: (1) finding the loss in weight of metal after immersion of small test pieces of the common pipe materials; (2) determining the drop in dissolved oxygen content of the water after passing, at a fixed rate of flow, through a considerable length of the pipe under test; or (3) determining reduction in a cross-sectional area of the test piece by measuring tensile strength or electrical resistance. Methods based on gain in weight of the pipe or increase in iron content of the water after passage through the pipe would not alone indicate total corrosion. The two effects would have to be considered together, being obviously complementary to each other. Actually the dissolved oxygen and immersion methods are by far the most convenient to use.

The dissolved oxygen method requires considerable space and equipment and, it would appear to be difficult to avoid loss of dissolved oxygen with the air bubbles released upon heating the water. The immersion method, on the other hand, does not present these particular disadvantages, but it does pose the problem of removing, cleanly, all corrosion products from the test pieces before final weighing, accuracy depending upon how efficiently this is done. In the study reported here the immersion method was used, the degree of corrosion being indicated by the loss in weight and mean depth of penetration of attack.

Procedure of Tests

Test pieces were cut from standard lengths of $\frac{3}{4}$-inch pipe, purchased in the open market, and were machined to about 1.273 in. in length, that is, $\frac{4}{\pi}$ in. The pieces were washed twice in benzol, then in alcohol and in hot water, removing all paint and grease. Then the weight of each was determined to the nearest 0.1 mg., using a chemical balance. Measurements of wall thickness, outside diameter and length were made with micrometer calipers. Twenty specimens of each metal were also weighed in water to determine average density values necessary for calculating volume, surface and

mean penetration of corrosion. Data regarding the pipe samples investigated are given in Table 1.

The entire surface area of all test pieces, except those of galvanized iron, was exposed to attack. In the case of the galvanized iron, it was necessary to mask the cut ends to prevent accelerated corrosion of the zinc due to electrolytic action. This was accomplished by dipping the ends of the pieces in a cellulosic lacquer (Cenco label varnish); covering them with a circular ring, cut from cartridge paper, to protect the lacquer from mechanical wear while under test; and waterproofing them by a second application of lacquer. This process thus provided a protective end covering easily removable with amyl acetate.

At the end of the testing period the products of corrosion and all protective coatings were removed as carefully as possible by a combination of methods, including scrubbing under water with a test tube brush, rubbing with a cloth towel, scraping with a wooden point, and the careful use of steel so as to remove all appreciable deposit without damaging the unattacked metal and without attempting to remove the last traces or stains. Brass and copper test pieces were cleaned by immersing for a few seconds in dilute ammonia solution. After cleaning, the samples were again weighed to determine loss in weight.

TABLE 1

Cost and Density Values for Pipe Under Test

TYPE OF PIPE	PRICE PER 100 FT.	DENSITY
Copper	$32.30	8.9332
Brass (Anaconda 67)	29.91	8.5157
Genuine wrought iron	9.78	7.5664
Copper bearing iron	8.60	7.8401
Galvanized iron	8.10	—
Black iron	6.43	7.8389

The test pieces were supported within testing chambers consisting of glass pots through which the water under test was allowed to flow. The pots were pyrex filter mantles, 13 in. high and 4 in. in inside diameter, as supplied for use with Berkfeld filters. Each has a hole, in the center of the base, which makes a convenient outlet for the overflow tube. The metal test specimens were arranged in six vertical columns of five pieces, one column of each variety of pipe, each

column being supported internally by two lengths of pyrex glass rod, 8 mm. in diameter; and, in order to reduce electrolytic effects to a minimum, each piece was separated from adjacent pieces in the column by $\frac{1}{2}$-inch separators cut from 25 mm. pyrex tubing. The supporting rods pass through brass plates, at top and bottom, which serve to hold them in a vertical position, the upper ends of the rods

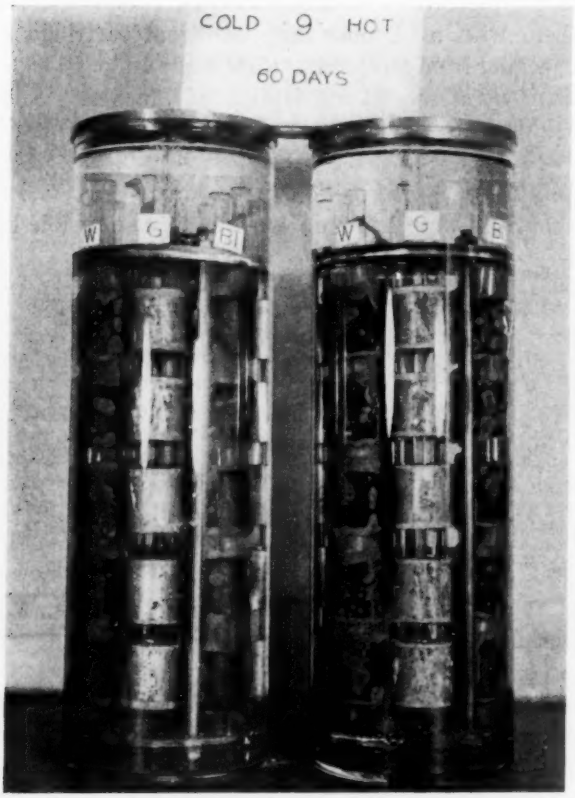

FIG. 1. Corrosion Test Chambers; showing arrangement of specimens under test

being flattened to form a head to prevent their dropping out when the assembly was lifted. The two brass end plates are drilled with holes to allow circulation and are tied together by two 11-inch bolts made from a $\frac{1}{4}$-inch Tobin bronze rod, enabling the whole assembly of test pieces and supports to be handled as a unit and thus simplifying insertion or removal from the corrosion chamber. A brass cover

plate in which two holes are drilled for a thermometer and the pyrex water supply line which leads to the underside of the bottom supporting plate, together with a pyrex overflow tube passing up through the center to near the top of the chamber, complete the corrosion chamber assembly. In Fig. 1 are shown two such corrosion chambers and the arrangement of their test pieces which in the particular example have been exposed for 60 days to the action of Ottawa filter effluent treated with sodium silicate (18 to 20 p.p.m. SiO_2).

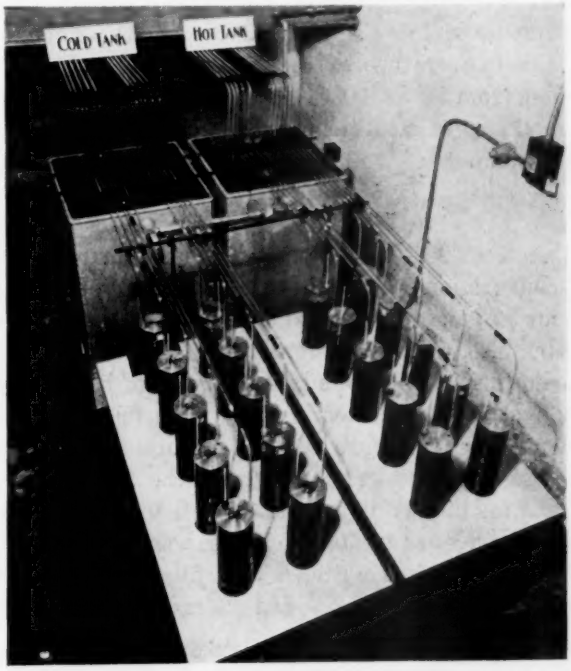

FIG. 2. Arrangement of Corrosion Testing Equipment, including temperature control tanks and corrosion test chambers

Covered oak barrels of 40 gal.* capacity serve as reservoirs in which the treatment is applied and from which the water runs through pyrex tubing, 8 mm. in inside diameter, to the corrosion test chambers, all connections in glass tubing being made by means of a sleeve of pure gum rubber tube wired to the glass tubes. Flow in each line is regulated by a stop-cock, bypassed in each instance by a short loop

* All values in gallons throughout this paper refer to Imperial gallons. (1 Imperial gallon = 1.2 U. S. gallons.)

fitted with a pinch-cock for flushing the line without interfering with the stop-cock setting. At a point between the barrels and the test chambers the glass tubing branches two ways and U-shaped sections of the branch lines are immersed in covered hot and cold water tanks, respectively, for temperature control, the branch lines then leading to the respective hot and cold test chambers (Fig. 2). A continuous flow of tap water, with an annual temperature range of from 33 to 80°F. circulates in the cold tank while in the insulated hot tank a thermostatically controlled immersion heater maintains an even temperature of 180°F. The hot corrosion chambers were not insulated, the temperature of the water in contact with the test pieces ranging from 80 to 100°F. depending upon room temperature, this corresponding to conditions that might obtain in the average household system.

Waters Studied

The barrels were filled and treated every day and the rate of flow through each corrosion pot was regulated to 50 ml. per min., or a total flow of about 32 gal. per 24 hr. from the barrel. Because of formation of air bubbles, which tend to diminish the rate of flow, particularly in the hot lines, it was found necessary to flush out the lines for a few seconds at $1\frac{1}{2}$-hour intervals. Two barrels were filled with Ottawa river water, one untreated and the other treated with chloramine. These correspond respectively to the city supply until the year 1912 and for the period from 1917 to 1932 when the chloramine treatment, as developed by Joseph Race, was applied continuously. The other eight barrels were filled with filtered water subjected to various types of treatment. The ten waters studied were as follows:

1. *Raw river water.* pH 6.9 to 7.4; color, 40 to 80; alkalinity, 12 to 38 p.p.m. and total hardness 35 to 70 p.p.m. Temperature varied from 32–33°F. in winter to a maximum of 80° in August.

2. *Raw water plus chloramine.* Treatment was by means of bleaching powder and aqua ammonia, the dosage being equivalent to 1.0 p.p.m. chlorine. Ratio of NH_3 to Cl_2 was 1:3.; pH was 7.1 to 7.5.

3. *Filter effluent.* Ottawa river water which has been coagulated and filtered for color removal. The alum used varies from $2\frac{1}{8}$ to $2\frac{3}{4}$ g.p.g., this dosage being a function of raw water alkalinity. Color was 3 to 4; alkalinity, 2 to 3 p.p.m.; pH, 5.8 to 6.2.

4. *Filter effluent plus lime.* To raise the pH to slightly above the neutral point. Dosage, about 0.70 g.p.g.; pH, 7.1 to 7.4.

5. *Filter effluent plus lime.* To raise the pH to slightly above the calcium carbonate solubility equilibrium value. Dosage, 0.80 to 1.00 g.p.g.; pH, 8.6 to 9.0.

6. *City tap water.* Filter effluent treated in the plant with about 0.80 g.p.g. lime (CaO) and from 3 to 5 lb. per mil.gal. chlorine. Color, 4 to 6; total alkalinity, 20 to 42 p.p.m.; phenolphthalein alkalinity, 1 to 5 p.p.m.; chlorides, 2 to 4 p.p.m.; total solids, 70 to 85 p.p.m.; sulfate, 18 to 23 p.p.m.; pH, 8.4 to 9.1.

7. *Filter effluent plus soda ash.* To give pH value same as tap water. Dosage equivalent to 1.7 to 3.5 g.p.g. of Na_2CO_3; pH, 8.5 to 9.1.

8. *Filter effluent plus sodium silicate.* Dosage equivalent to 7 p.p.m. SiO_2. This was a silicate with a high Na_2O:SiO_2 ratio of 1:2.00. Dosage equivalent to 241 lb. per mil.gal. silicate; pH, 6.3 to 6.6.

9. *Filter effluent plus sodium silicate.* Treatment was sufficient to raise the pH to about the neutral point or slightly above it, this requiring a dosage of silicate equivalent to 18 to 20 p.p.m. of SiO_2 (620 to 690 lb. per mil.gal. silicate); pH, 6.9 to 7.3.

10. *Filter effluent plus lime.* To give tap pH. Test is duplicate of No. 5.; pH 8.6 to 9.1.

Test Results

In order to develop corrosion-time diagrams one sample of each metal was removed from each corrosion chamber after intervals of 60, 214, 429, 617 and 792 days exposure, the test being initiated on September 26, 1938, and terminated on November 26, 1940. There being no appreciable attack on the copper and brass samples at the end of 60 days, none of these was removed at that time, thus allowing removal of duplicate test pieces after 792 days.

Results are expressed in terms of mean penetration of corrosion, obtained by dividing loss in weight by the product of density and surface of the test piece. This unit affords a valid basis of comparison for total corrosion of test pieces of different density and different shape or surface-volume ratio. It is, however, not satisfactory in the case of galvanized iron because of the non-uniformity of the pipe as regards density, so for this pipe material, corrosion has been recorded in terms of loss in weight per unit of surface. Penetration values obtained are shown in Table 2, while loss in weight for the galvanized

TABLE 2

Mean Penetration of Corrosion of Test Pieces in Inches $\times 10^{-4}$

BARREL NO.	WATER	CONTACT	DAYS EXPOSURE	COPPER	BRASS (ANACONDA 67)	BLACK IRON	GENUINE WROUGHT IRON	COPPER BEARING IRON
1	Raw water. pH 7.0–7.2	Cold	60	—	—	2.58	3.24	3.97
			214	0.35	0.65	8.59	8.44	11.69
			429	0.92	1.51	15.58	16.41	20.63
			617	1.33	2.30	24.25	24.04	28.30
			792	1.80	2.96	23.71	33.87	40.36
			792	1.66	3.26	—	—	—
		Hot	60	—	—	6.29	6.71	12.27
			214	0.64	1.21	22.02	22.15	39.03
			429	1.38	2.79	38.80	40.11	66.73
			617	2.30	4.64	67.73	69.88	79.23
			792	2.92	6.70	90.90	90.85	98.64
			792	3.07	6.39	—	—	—
2	Raw water plus chloramine. pH 7.1–7.5	Cold	60	—	—	3.00	3.93	3.99
			214	0.38	0.57	7.95	15.52	15.15
			429	0.86	1.35	24.02	27.83	25.71
			617	1.18	1.96	36.73	29.22	34.09
			792	1.44	2.03	38.51	34.51	45.08
			792	1.36	2.14	—	—	—
		Hot	60	—	—	4.50	5.34	11.00
			214	0.68	0.98	24.37	22.53	36.54
			429	1.21	2.22	40.09	40.55	53.75
			617	1.56	3.19	55.25	54.94	68.13
			792	2.03	4.47	76.16	74.36	87.29
			792	2.02	4.21	—	—	—
3	Filter effluent. pH 5.8–6.2	Cold	60	—	—	3.89	4.50	7.04
			214	0.68	1.29	13.35	15.61	18.33
			429	1.72	2.72	27.03	29.35	33.23
			617	2.60	4.31	36.67	41.85	46.89
			792	3.12	6.09	46.45	50.80	63.13
			792	3.67	5.09	—	—	—
		Hot	60	—	—	3.51	4.51	8.91
			214	1.33	2.54	21.24	20.62	30.12
			429	3.48	6.66	44.66	43.35	61.14
			617	4.95	9.81	66.41	63.90	73.58
			792	6.57	12.48	94.85	94.20	100.58
			792	7.37	13.78	—	—	—

TABLE 2—*Continued*

BARREL NO.	WATER	CONTACT	DAYS EXPOSURE	COPPER	BRASS (ANACONDA 67)	BLACK IRON	GENUINE WROUGHT IRON	COPPER BEARING IRON
4	Filter effluent plus lime. pH 7.1–7.4	Cold	60	—	—	4.51	4.24	6.27
			214	0.26	0.41	12.25	13.04	20.32
			429	0.64	1.21	25.12	25.04	36.29
			617	0.98	1.62	31.19	33.76	43.74
			792	1.02	1.81	38.88	45.34	54.72
			792	1.73	1.86	—	—	—
		Hot	60	—	—	4.89	5.05	9.11
			214	0.35	0.59	23.51	24.10	35.22
			429	0.70	1.41	39.52	48.67	77.01
			617	1.20	2.49	70.54	74.08	97.95
			792	1.49	3.09	93.97	100.12	120.35
			792	1.99	3.23	—	—	—
5	Filter effluent plus lime. pH 8.6–9.0	Cold	60	—	—	4.77	5.35	5.99
			214	0.06	0.13	13.79	14.14	18.10
			429	0.12	0.35	23.84	24.46	31.63
			617	0.20	0.59	30.35	33.23	40.39
			792	0.24	0.62	36.30	38.38	46.53
			792	0.36	0.84	—	—	—
		Hot	60	—	—	4.38	4.20	11.36
			214	0.11	0.04	20.73	23.60	36.58
			429	0.19	0.25	44.71	48.50	57.27
			617	0.33	0.45	60.40	63.48	68.99
			792	0.37	0.49	77.72	75.00	82.57
			792	0.36	0.61	—	—	—
6	Ottawa tap water.	Cold	60	—	—	4.29	4.77	5.92
			214	0.04	0.05	13.94	12.85	16.56
			429	0.04	0.12	29.72	32.47	29.89
			617	0.09	0.28	34.38	35.56	37.75
			792	0.09	0.31	44.18	49.53	47.14
			792	0.11	0.29	—	—	—
		Hot	60	—	—	4.75	4.97	7.96
			214	0.04	0.04	20.48	26.27	38.56
			429	0.11	0.10	42.40	53.37	56.59
			617	0.11	0.16	56.32	71.02	63.96
			792	0.21	0.25	76.02	91.43	75.14
			792	0.23	0.28	—	—	—

TABLE 2—*Continued*

BARREL NO.	WATER	CONTACT	DAYS EXPOSURE	COPPER	BRASS (ANACONDA 67)	BLACK IRON	GENUINE WROUGHT IRON	COPPER BEARING IRON
7	Filter effluent plus soda ash. pH 8.5-9.1	Cold	60	—	—	5.95	5.50	5.59
			214	0.06	0.13	15.98	15.92	17.99
			429	0.15	0.25	33.89	35.69	32.51
			617	0.18	0.32	40.84	41.70	42.52
			792	0.18	0.39	54.35	53.15	57.41
			792	0.23	0.45	—	—	—
		Hot	60	—	—	5.32	5.41	6.51
			214	0.10	0.08	27.14	27.91	33.14
			429	0.16	0.19	43.50	43.69	56.56
			617	0.22	0.33	68.22	66.81	76.48
			792	0.34	0.26	88.75	80.80	97.13
			792	0.27	0.43	—	—	—
8	Filter effluent plus sodium silicate. pH 6.3-6.6	Cold	60	—	—	5.31	5.81	5.00
			214	0.89	1.15	15.68	13.96	16.96
			429	1.94	2.64	28.14	26.08	32.83
			617	2.56	4.14	37.40	38.18	40.45
			792	3.27	5.25	46.00	50.41	55.88
			792	3.37	5.27	—	—	—
		Hot	60	—	—	4.23	3.84	8.77
			214	1.07	1.64	16.03	17.52	31.97
			429	2.08	4.24	35.33	40.76	78.15
			617	2.95	5.96	54.51	62.74	97.87
			792	3.95	8.11	86.22	92.98	127.15
			792	4.17	7.61	—	—	—
9	Filter effluent plus sodium silicate. pH 6.9-7.3	Cold	60	—	—	4.20	4.65	5.11
			214	0.27	0.35	14.70	13.35	15.75
			429	0.73	0.97	23.94	23.89	30.71
			617	1.17	1.32	32.08	33.54	38.79
			792	1.21	1.66	39.04	39.74	47.33
			792	1.21	1.71	—	—	—
		Hot	60	—	—	4.62	4.90	9.46
			214	0.42	0.58	22.31	22.85	35.03
			429	0.81	1.15	36.86	37.26	49.30
			617	1.07	1.78	50.25	62.57	68.22
			792	1.40	2.23	69.46	78.62	86.88
			792	1.44	2.60	—	—	—

TABLE 2—*Concluded*

BARREL NO.	WATER	CONTACT	DAYS EXPOSURE	COPPER	BRASS (ANACONDA 67)	BLACK IRON	GENUINE WROUGHT IRON	COPPER BEARING IRON
10	Filter effluent plus lime. pH 8.6–9.1	Cold	60	—	—	4.81	4.83	6.82
			214	0.05	0.05	12.81	14.85	18.45
			429	0.12	0.16	23.06	25.35	35.39
			617	0.21	0.55	31.67	35.42	44.70
			792	0.42	0.50	39.86	39.97	50.31
			792	0.34	0.70	—	—	—
		Hot	60	—	—	6.60	5.27	6.16
			214	0.08	0.06	23.63	23.15	24.14
			429	0.14	0.15	40.26	48.51	50.23
			617	0.20	0.41	57.50	60.30	64.82
			792	0.26	0.58	78.87	83.90	82.14
			792	0.29	0.53	—	—	—

iron pieces is listed in Table 3. For approximate comparison, a factor of 0.085 may be used to convert the values in Table 3 to the basis used in Table 2, this factor being based on the density of metallic zinc.

The corrosion-time diagrams obtained should indicate whether or not additional protection against corrosion, i.e. reduction in corrosion rate, has developed during the test, either by the accumulation of corrosion product or by coatings induced by the protective treatment. Such diagrams for copper and brass are shown in Fig. 3.

As would be expected, attack is greater with hot than with cold water. Copper is more resistant than brass, although both are vastly superior to the various iron pipes for all water treatments studied. They are less attacked by water of alkaline pH than of acid pH, the attack by water of neutral pH being intermediate. Ottawa tap water is shown to be the least aggressive against these pipe materials, the present protective treatment of this supply resulting in a 90 per cent reduction of attack on copper and brass pipe as compared to that by untreated filter effluent.

The corrosion-time diagrams show no appreciable flattening out or decrease in slope that would indicate reduction in corrosion rate such as might be expected from the gradual deposition of a protective coating. In colored unfiltered water a brownish film is formed. In untreated filter effluent slight pitting occurs with formation of reddish

TABLE 3

Loss in Weight in Milligrams per Square Inch for Galvanized Iron After Various Periods of Contact

BARREL NO.	WATER	60 DAYS		214 DAYS		429 DAYS		617 DAYS		792 DAYS	
		Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot
1	Raw water. pH 7.0–7.2	8.83	14.80	30.43	33.02	59.73	74.80	79.91	144.86	96.47	243.17
2	Raw water plus chloramine. pH 7.1–7.5	8.10	11.30	18.00	28.40	42.30	82.70	53.90	99.10	87.34	121.33
3	Filter effluent. pH 5.8–6.2	23.30	25.75	52.88	83.29	106.88	257.96	153.98	338.52	211.81	490.53
4	Filter effluent plus lime. pH 7.1–7.4	12.79	13.90	21.95	33.80	45.81	55.39	51.18	83.02	69.10	120.50
5	Filter effluent plus lime. pH 8.6–9.0	11.24	11.50	24.48	23.18	43.52	66.89	48.16	94.02	46.84	113.13
6	Ottawa tap water. pH 8.4–9.1	7.10	11.70	12.90	23.00	28.90	55.70	34.00	84.50	47.80	134.59
7	Filter effluent plus soda ash. pH 8.5–9.1	9.13	7.51	19.22	20.33	33.90	40.30	36.83	50.31	51.20	83.63
8	Filter effluent plus sodium silicate. pH 6.3–6.6	18.30	21.14	52.31	60.03	88.60	161.91	114.91	268.94	178.15	366.01
9	Filter effluent plus sodium silicate. pH 6.9–7.3	15.34	15.34	22.61	50.89	61.18	78.36	84.66	102.16	93.21	138.45
10	Filter effluent plus lime. pH 8.6–9.1	5.94	12.99	19.39	23.79	32.06	40.16	32.47	65.63	41.33	86.26

cuprous oxide and some dezincification in the case of brass. Sodium silicate treatment causes the formation of a thin greenish-colored protective film, while lime and soda ash treatments at the higher pH values leave the metal clean and bright without deposition of lime

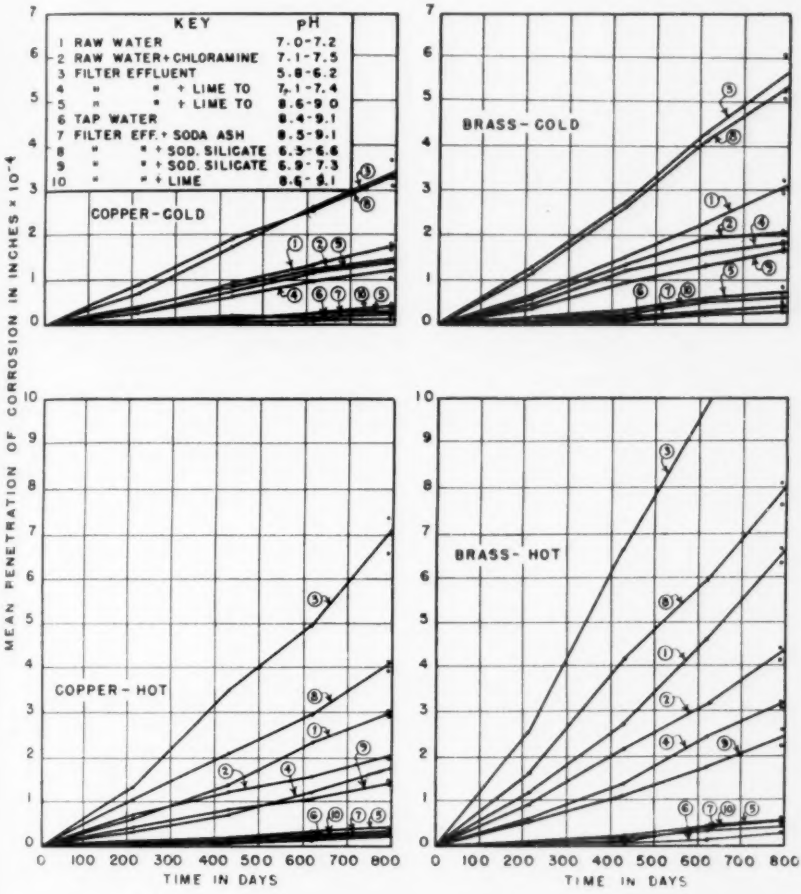
KEY
pH
1 RAW WATER 7.0-7.2
2 RAW WATER + CHLORAMINE 7.1-7.5
3 FILTER EFFLUENT 5.8-6.2
4 " " + LIME TO 7.1-7.4
5 " " + LIME TO 8.6-9.0
6 TAP WATER 8.4-9.1
7 FILTER EFF. + SODA ASH 8.5-9.1
8 " " + SOD. SILICATE 6.5-6.6
9 " " + SOD. SILICATE 6.9-7.3
10 " " + LIME 8.6-9.1
COPPER-COLD
BRASS-COLD
COPPER-HOT
BRASS-HOT
MEAN PENETRATION OF CORROSION IN INCHES x 10⁻⁴
TIME IN DAYS
0 100 200 300 400 500 600 700 800

FIG. 3. Corrosion-Time Diagrams for Copper and Brass

coating, a condition favorable to the use of these metals for certain special purposes, e.g., in water meter construction, with a water supply which deposits lime on iron pipe.

Similar corrosion-time diagrams for black iron, copper bearing iron and wrought iron (plotted on a different scale) are shown in Fig.

4 A, B and C. In most cases there appears to be little difference in total corrosion between black and wrought iron, the included slag in the latter apparently having no value as a protective agent. Both

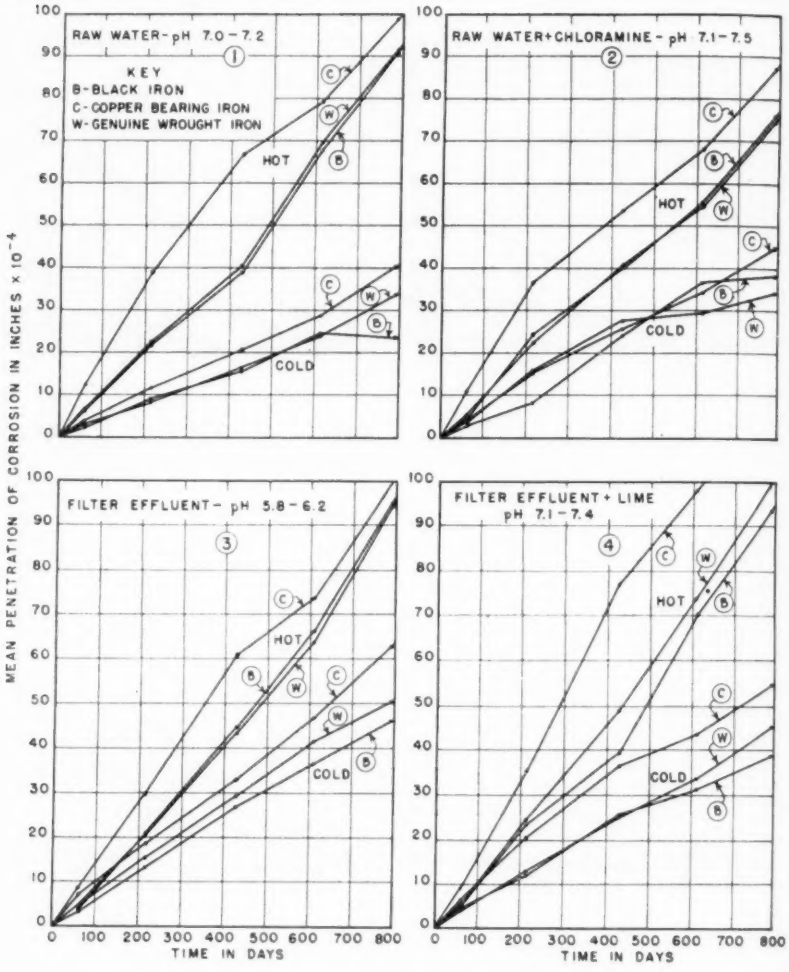

FIG. 4A. Corrosion-Time Diagrams for Various Types of Iron

varieties show a tendency towards pitting. Copper-bearing iron suffers greater attack, but this is more evenly distributed over the surface of the test piece and the pipe would probably have the longer life because of reduced pitting. In this case, the bond between rust

and metal is very weak and the pieces are easily cleaned, leaving a bright metal surface. It is only fair to point out that this last type of pipe is intended primarily to withstand atmospheric corrosion

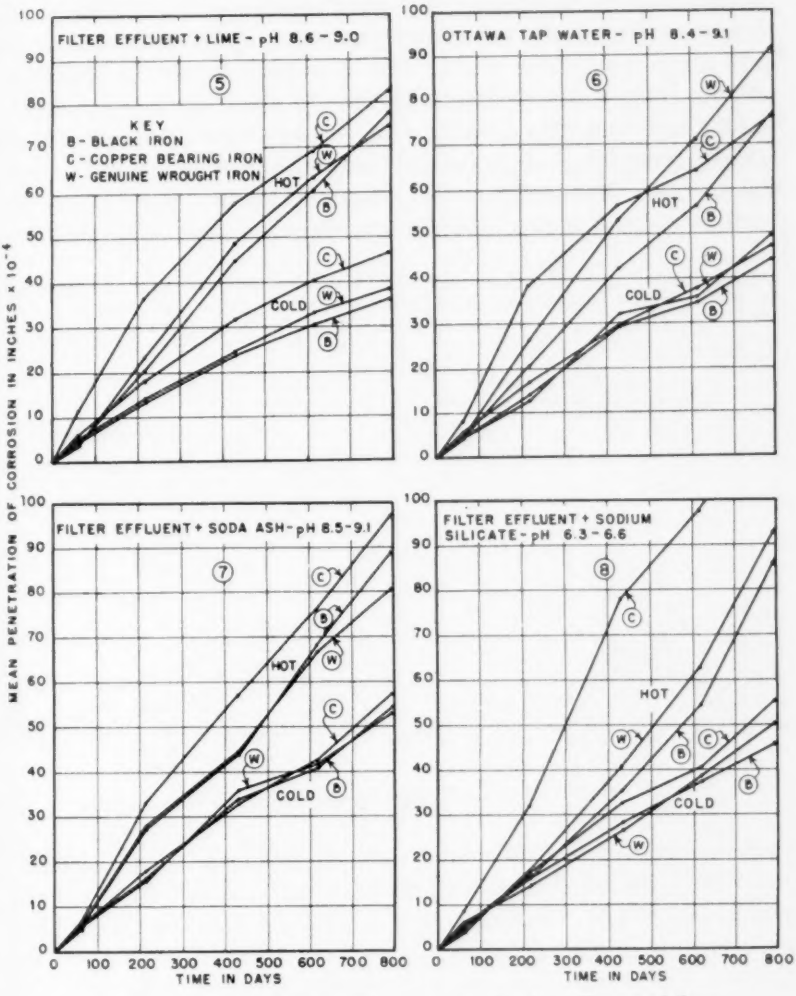
FILTER EFFLUENT + LIME - pH 8.6 - 9.0
OTTAWA TAP WATER - pH 8.4 - 9.1
FILTER EFFLUENT + SODA ASH - pH 8.5 - 9.1
FILTER EFFLUENT + SODIUM SILICATE - pH 6.3 - 6.6
KEY
B - BLACK IRON
C - COPPER BEARING IRON
W - GENUINE WROUGHT IRON
HOT
COLD
MEAN PENETRATION OF CORROSION IN INCHES x 10⁻⁴
TIME IN DAYS

FIG. 4B. Corrosion-Time Diagrams for Various Types of Iron

rather than underwater attack. With the possible exception of that for Barrel No. 5, the corrosion-time diagrams do not indicate that protective coatings gradually increase resistance to corrosion to any great extent.

Examination of the iron test pieces from treatments with lime and with soda ash shows that certain irregular areas of unattacked metal are covered with a lime coating, corrosion taking place between these protected areas, which gradually decrease in extent and finally disappear as the period of exposure lengthens. Thus it would appear that areas which are neither attacked nor covered by corrosion product for a sufficient length of time to allow the formation of a tightly adhering lime coating are able to resist direct or surface attack, corrosion being centered on and spreading laterally from those areas which suffer early corrosive attack. Much value has been attributed to the protective function of such a lime coating,

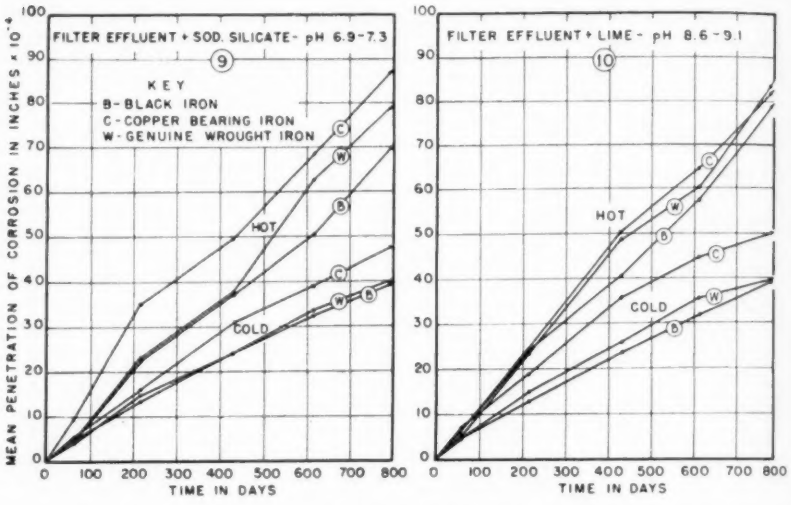

FIG. 4C. Corrosion-Time Diagrams for Various Types of Iron

but it is apparent that its presence and extent depend upon conditions inherent in the metal itself and that the protection afforded is not of a permanent nature. Again, benefit has been attributed to the presence of lime in the corrosion product where it is said to cause the formation of a more compact and tougher deposit. While this last might tend to reduce "red water," the rate of corrosion in the instance under discussion does not appear to be reduced to any great extent, the toughening effect of lime possibly being offset by the presence of organic coloring matter. Absolute zero color is never obtained by coagulation and some of this residual color is concentrated by and in the corrosion product.

Theoretically, lime coating cannot be produced in a water of pH below the solubility-equilibrium value, but such coatings were obtained on iron pipe samples exposed to water from Barrel No. 4, which is filter effluent raised by lime to slightly above neutral pH. Such an effect suggests that the lime may be, at least in part, otherwise than in true solution.

Treatment of the water with sodium silicate results in the deposit of a thin tough film on the test pieces. The corrosion product formed in raw river water is at first particularly gelatinous and bears much organic coloring matter, while treatment with chloramine causes the formation of a much harder and more compact deposit on the test

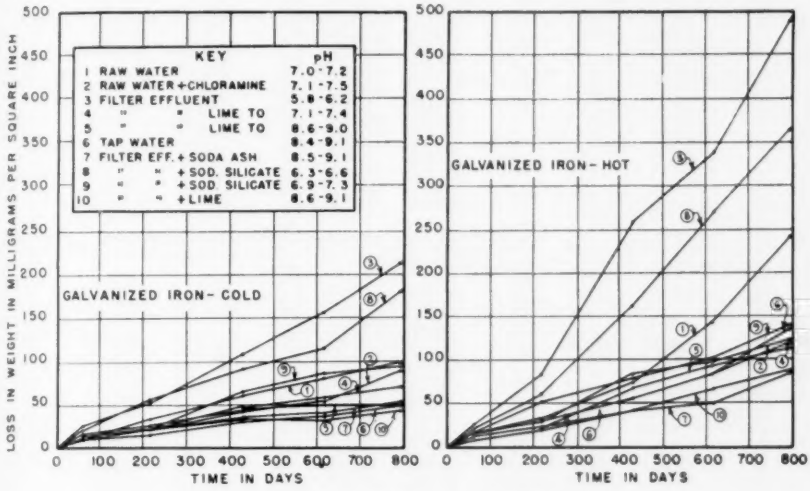
LOSS IN WEIGHT IN MILLIGRAMS PER SQUARE INCH
KEY
pH
1 RAW WATER 7.0-7.2
2 RAW WATER + CHLORAMINE 7.1-7.5
3 FILTER EFFLUENT 5.8-6.2
4 " " LIME TO 7.1-7.4
5 " " LIME TO 8.6-9.0
6 TAP WATER 8.4-9.1
7 FILTER EFF. + SODA ASH 8.5-9.1
8 " " + SOD. SILICATE 6.3-6.6
9 " " + SOD. SILICATE 6.9-7.3
10 " " + LIME 8.6-9.1
GALVANIZED IRON - COLD
GALVANIZED IRON - HOT
TIME IN DAYS
TIME IN DAYS

FIG. 5. Corrosion-Time Diagrams for Galvanized Iron

pieces. Control of corrosion on the varieties of iron pipe tested appears to be very limited, the protection afforded by the present treatment of the Ottawa filtered water supply being about a 10 per cent reduction of attack, although a coating of "egg-shell" thickness covered parts of the test pieces.

As in most other cities, the average household water supply system in Ottawa consists of galvanized iron piping. Therefore, of all the tests carried out, those on this type of pipe are of most significance in determining the value of any particular water treatment. In Fig. 5 are shown the corrosion-time diagrams obtained, the results indicating that this type of pipe is, on the average, 10 or 12 times as

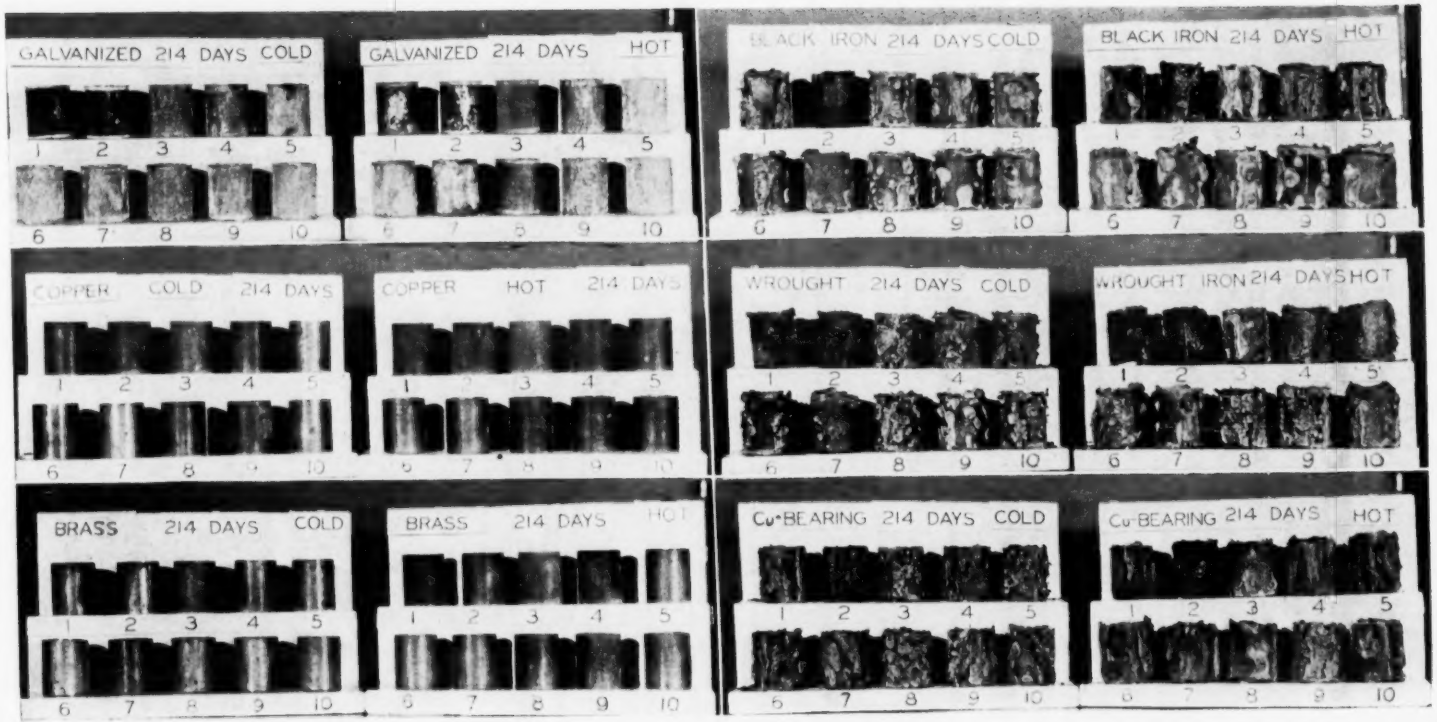
GALVANIZED 214 DAYS COLD
GALVANIZED 214 DAYS HOT
BLACK IRON 214 DAYS COLD
BLACK IRON 214 DAYS HOT
COPPER COLD 214 DAYS
COPPER HOT 214 DAYS
WROUGHT 214 DAYS COLD
WROUGHT IRON 214 DAYS HOT
BRASS 214 DAYS COLD
BRASS 214 DAYS HOT
Cu-BEARING 214 DAYS COLD
Cu-BEARING 214 DAYS HOT

FIG. 6. Test Pieces after 214 Days Contact

resistant as any type of unprotected iron pipe. Here, of the treatments investigated, water of acid characteristics shows the most rapid attack, the zinc coating being rapidly dissolved, while water of alkaline pH shows least attack and neutral waters give intermediate results. In these respects the pipe is similar to copper and brass pipe.

Conclusions

A comparison of the various corrosion-time diagrams indicates that the filtered water supply is less aggressive than raw water or chloramine treated raw water as pumped to the city before the present purification plant was constructed. Of the protective treatments studied, the present treatment with lime would appear to be equalled in results on galvanized iron pipe only by treatment with soda ash, a method which is not as satisfactory for the other types of iron pipe and which would increase alkaline treatment costs tenfold. The present treatment with lime reduces the aggressiveness of the filtered water on galvanized pipe to about 70 per cent.

The character of the corrosion product formed in colored raw water is of interest. Figure 6 shows samples of galvanized iron of which the first two have been exposed to water from Barrels No. 1 and 2. The natural color substances present in the water become intimately associated with the corrosion product as is readily seen in the illustration.

Figure 6 is a series of photographs of the test pieces taken before cleaning and after 214 days contact with water from the ten barrels, both hot and cold tests. These illustrations show: (1) the inclusion of organic coloring matter in the corrosion product formed on galvanized iron (already mentioned) and on other iron pipe when exposed to the colored river water; (2) the maximum attack on galvanized iron exposed to filter effluent (Barrel No. 3) and the only slightly less attack by Treatment 8, both of these water samples being of acid pH; (3) the comparative freedom from attack exhibited by copper and brass; (4) the tubercules covering localized attack on the black and wrought iron samples; and (5) the tougher and more extensive rust deposit on copper bearing iron, especially when exposed to hot water.

For this particular water supply it would appear that the use of lime can still be considered the most economical and effective treatment. It is quite probable that in water supply systems where the

water is already of neutral or alkaline pH, small dosages of the more expensive treatment chemicals can be used to advantage. On the other hand, when the treatment is primarily concerned with adding considerable alkalinity to a water of acid pH, as in this instance, the necessary dosages of such materials then become too large and the treatment much too costly to be considered. Since this series of tests was first planned a new treatment chemical, sodium hexametaphosphate, has been recommended for corrosion control. Data of a comparative nature are, however, still lacking in the literature and a similar test for this material would be necessary.

These experiments have supplied data which make it easy to show the economy possible in using the more expensive copper and brass pipe, which are in a class by themselves as regards resistance to corrosion. Based on the figures obtained, a very conservative estimate of comparative life of copper pipe exposed to Ottawa tap water would be more than 300 times that of pipe made from any type of unprotected iron and more than 30 times that of galvanized iron, a very great advantage in addition to that of elimination of iron rust from the piping system. The original cost of copper or brass pipe of equal wall thickness is not more than 5 times the cost of the cheapest iron piping. It is also very evident from these results that there is little to choose between black iron and wrought iron in respect to corrosion resistance when exposed to the particular water samples studied, and the additional 50 per cent in cost of the wrought iron does not buy any additional length of life or decrease in possible red water trouble.

This study was planned and carried out at the request of W. E. MacDonald, Ottawa City Water Works Engineer. The author also acknowledges his indebtedness to C. D. Wight, Assistant Water Works Engineer, and to the members of the operating and maintenance staff at the Ottawa Water Purification Plant, particularly G. L. Kerr, Laboratory Assistant, without whose assistance and co-operation the experiments could not have been carried out.

Investigating Water Quality in a Distribution System

By Albert M. Shannon and William M. Wallace

SINCE considerable attention has been focused upon the quality of the water delivered to the consumer and since various water supplies have been blamed for scattered gastro-enteritis outbreaks, it was decided to investigate conditions in the Detroit distribution system, with particular attention to those portions in which there was little or no circulation. This investigation was designed to answer four general questions:

1. What, if any, significance is to be attached to the presence of the bacteria found in the distribution system, particularly the slow lactose fermenters and the spore forming lactose fermenting organisms?

2. May any after-products or toxic compounds, resulting from the purification process and forming in the distribution system, prove irritating to the intestinal tract, and if so, are they the result of biochemical or biological action?

3. What is the best method of eliminating tastes and odors in the quiescent portions of the distribution system?

4. Are the present standards of water quality satisfactory? (It is known that they have been adequate to reduce water-borne typhoid and cholera outbreaks to a rarity, but can the attacks of gastro-enteritis which have been blamed, perhaps hastily and falsely, upon the water be eliminated also? It would be very advantageous to be in a position to state whether these attacks have been caused by water conditions.)

It is realized that such a program is too ambitious to be completed in a short time; and that the questions which have been raised may

A paper presented on June 24, 1941, at the Toronto Convention by Dr. Albert M. Shannon, Senior Sanitary Chemist, and William M. Wallace, Superintendent of Filtration and Sewage Treatment, Department of Water Supply, Detroit, Mich.

never be answered definitely. By conducting a careful, well-organized research, however, it is hoped that some light will be shed upon them. At present the investigation has been limited to the study of the bacteria in the distribution system and their possible public health significance. This paper, therefore, is more in the nature of a preliminary progress report than a record of completed work.

Organisms Causing Gastro-Enteritis

Upon studying the case histories of various gastro-enteritis outbreaks, water-borne and otherwise, it was found that many bacteria were thought to be implicated and, no doubt, many others have not as yet been discovered. Some of these organisms were: the various strains of *Shigella dysenteriae; Shigella paradysenteriae;* members of the *Salmonella enteritidis* group and certain strains of Staphylococci which are usually associated with food poisoning; *Salmonella morgani,* the organism frequently responsible for summer diarrheal diseases in children; late lactose fermenting coliform organisms; and *Bacterium coli mutabile.*

Few of these organisms, however, have been associated with water-borne gastro-enteritis. In too many instances, the agent responsible for an alleged water-borne outbreak has not been determined. The only way that precise information can be obtained as to the nature of these epidemics is through the isolation of known or suspected pathogens from stool specimens of the sufferers and the determination of the pathogenicity of the organism by serological tests with the serum from recovered patients. If these same organisms are found in the water supply and if they agglutinate the organisms isolated from the patient, one can be reasonably certain that they had an etiological relationship to the gastro-enteritis and that it was water-borne. Likewise, failure to find the organism in the water supply over a period of time should remove all suspicion of its responsibility.

Development of Isolation Method

In the thorough search of the literature that was necessary before this study of the bacteria, toxins, and chemicals in the distribution system and in the dead ends could be initiated, it was surprising to find that little or no work had been done upon the method for isolating the organisms by which water-borne gastro-enteritis is probably carried. Thus it was necessary to conduct experiments and to develop a method of isolation before further progress was possible.

Using as test organisms stock cultures of the more hardy dysentery strains, the typhoid organisms and the members of the salmonella family that might be responsible for intestinal disorders, a method was developed which, although it was quite long, was as simple as possible and yet obtained reliable results and a high percentage of isolations.

Since a finished water contains very few organisms, it was necessary to collect large samples and to enrich them with a favorable medium for growth before there were sufficient organisms for study. Accordingly, 100 or 200 ml. or more of water were enriched with sterile tryptose and dextrose solution and incubated for 18 to 24 hr. at 37°C. The tryptose and dextrose solution was made by adding 10 grams tryptose and 5 grams dextrose to 100 ml. distilled water, sterilizing, and then adding 10 ml. of this solution to 100 ml. of sample.

Next an aliquot portion of 10 ml. was added to 50 ml. of tetrathionate broth base and incubated for 24 hr. at 37°C. This medium inhibited the coliform organisms, whereas the pathogens were permitted to grow almost unrestrictedly. Then, two poured plates of bismuth sulfite agar with 5 ml. and 1 drop inoculums, streak plates of MacConkey's agar and sodium sulfite agar were made. After 24-hour incubation at 37°C., well-isolated typical colonies were picked, inoculated into lactose broth, streaked on MacConkey's agar and picked again to ensure a pure culture for identification purposes. It was necessary to incubate the bismuth sulfite agar plates for 48 hr. since some of the typhoid strains are slow to develop. The typhoid organisms and some strains of salmonella grew well on bismuth sulfite agar and were detected very easily by their black colonies. The sodium sulfite agar inhibited the coliform organisms, while on the MacConkey's agar they developed a red color, and, on both media, the pathogens formed colorless colonies.

Since the enteric pathogens are all gram-negative rods, microscopic examination did not suffice to differentiate them. It was necessary, therefore, to resort to their biochemical differences with regard to various media. Kligler's iron agar served very well for a preliminary classification, but the slow lactose fermenting organisms gave misleading results in that they could be mistaken very easily for salmonella organisms. Krumwiede triple sugar agar will eliminate these false salmonella reactions of the slow lactose fermenters.

To determine the name of the organism isolated, it was necessary

to obtain enough information to trace it in Bergey's *Manual.* Knowledge as to the size of the organism; its staining characteristics; its motility; the appearance of the colonies on agar, gelatin, agar slants, gelatin stabs and in broth; the action of the organism on litmus milk and potato; its ability to form indol, produce nitrites, form hydrogen sulfide, to utilize citrate as a sole source of carbon, to form acetyl methyl carbinol (Voges-Proskauer test) and to produce acid (methyl red test); as well as its fermentation habits on certain carbohydrates—dextrose, lactose, sucrose, maltose, mannitol, galactose, xylose, arabinose, inositol, dulcitol, and dextrin—must be determined before the genera and species can be stated definitely.

This technique has been used successfully in recovering dysentery and paratyphoid bacteria that have been added to samples of water containing coliform organisms; and these enteric organisms have been found in sewage and in heavily polluted raw water using the same technique. All complaints where sickness, especially gastro-enteritis, was believed to have been caused by drinking city water have been subjected to study by the above method, and it is certain that if any responsible organisms were present at the time of sampling, the possibility for them to escape detection would be extremely remote.

Food Supply for Organisms

The question of food supply for the organisms in the distribution system has been an important one. There are innumerable soil organisms present in the Detroit raw water supply, and some of these are nitrifying bacteria which pass through the filters and are not killed by the chlorine doses administered. As a food supply these organisms use the ammonia and nitrites in the water, oxidize them to nitrates, which in turn are reduced to nitrites by other organisms. These nitrifying bacteria reach the quiescent portions of the distribution system, multiply and die and thus produce organic matter, which together with the small amount already in the mains eventually builds up enough organic matter to serve as a medium for other bacteria. Buswell and Suter* have substantiated this theory in part as they have shown that organisms oxidizing ammonia to nitrites, and nitrites to nitrates, exist in chlorinated water in the mains and

* Buswell, A. M. and Suter, Max. A Study of Floc-forming Organisms in Chlorinated Water Supplies. Jour. Bact., **39:** 583 (1940). Also certain unpublished comments before the A.W.W.A. Kansas City Convention of 1940.

are capable of forming a sludge. Thus, the idea that if a few organisms, pathogens or non-pathogens, escape the coagulation, filtration and chlorination treatment and reach the quiescent portions of the distribution system they might find a suitable place to multiply and possibly to produce toxins, is not too unreasonable to be taken into consideration.

Procedure of Study

It was believed that the best possible place to study the organisms and any toxins in the distribution system would be in the outlying districts and in the dead ends, for there the water moves slowly, if at all, and the chlorine residual has been reduced to a point low enough not to interfere with the multiplication of the bacteria. Accordingly, six dead ends, one in the filter plant grounds and five in widely scattered sections of the distribution system, were found and tapped. Care was taken to locate various sized mains in wells and, at present, there are dead ends in a 36-inch, 24-inch, two 12-inch and two 8-inch mains. These mains were tapped so as to give two leadoffs, one from the bottom of the main, the other from the top. In the case of the smaller mains, however, the two leadoffs are from the top with one extending through a corporation cock to within a half inch of the bottom. Thus it was possible to sample the sediment and also to sample the water from the top of the main. Rubber pressure tubing was connected to the leadoffs, which permitted the sample to be drawn off out of the well and allowed the sampling device to be lowered into the well below the frost line, when not in use. In this way samples could be collected during all seasons.

During the installation of the above leadoffs, care was taken to maintain aseptic conditions and, after installation, hypochlorite solution was allowed to stand in them overnight and flushed off in the morning before sampling was started.

It was surprising to find that the first samples taken from a dead end that had not been disturbed for years, were very clear and the bacterial count was quite low. After flushing for a short time, however, the water became very turbid, and the bacterial count rose. The above phenomena were no doubt due to the settling out effect in mains that have no flow and have not been disturbed for some time. This fact indicated the importance of obtaining a sample from the bottom of the main in order to obtain a true picture of its contents.

Samples have been collected every other week and the standard

bacteriological technique as set up by *Standard Methods* has been followed. Four pour-plates were incubated at 37° and two at 20°C. Two different agars were used, one, standard and the other, tryptone glucose extract, the latter being more favorable for the development of pathogenic bacteria and giving considerably higher bacterial counts. The plates were counted at least twice, since it was found that the *Standard Methods* time was too short to allow all colonies to develop to a point where they could be observed. In addition, the enrichment technique for the isolation of pathogens, as described earlier, was used on all samples. Each week a sample of the chlorinated plant effluent was examined in the same manner.

Findings of Study

The results (Table 1) showed that the average monthly bacterial count in the dead ends varied from 15 to 48,000 colonies per ml. on the 37°C. count and from 40 to 80,000 colonies per ml. on the 20°C. count. It must be remembered, however, that an enriched agar was used and that the time of incubation was increased from 24 hr. at 37°C. and 48 hr. at 20°C. (as specified in *Standard Methods*) to 96 hr. in both cases. When standard agar and the standard incubation time was used, very few colonies developed and the bacterial counts were well within the limits for a pure water. The chlorinated plant effluent, which always carries a chlorine residual from 0.15 to 0.20 p.p.m., gave a bacterial count ranging from 2 to 25 colonies per ml. when incubated at 37°C., and from 8 to 150 colonies per ml. when incubated at 20°C. for 96 hr., using the enriched agar, whereas using the *Standard Methods* technique, the average count, over a period of a year, was less than 1 colony per ml.

During the months of September and October, when the water in the mains reached its highest temperature, the highest average bacterial counts resulted. The counts, then, gradually decreased until March, when the lowest main temperatures were recorded.

Usually some of the lactose broth tubes, which did not confirm on brilliant green bile broth, produced gas in 48 hr. When these tubes were heated to 80°C. for some time, then re-inoculated into lactose broth, growth occurred and usually gas was again produced, thus proving that spores were present and responsible for the lactose fermentation, since they alone are able to withstand that temperature. Microscopic examination confirmed the presence of the spores and showed that at least three different varieties of gram-positive spore

forming rods were present. Streak plates were made and well isolated colonies were picked into lactose broth. Only a few of the tubes, however, showed the presence of gas, although growth occurred in all. This indicated that it might be necessary for a combination of spore formers to be present in order to produce gas in lactose broth. The study, however, was only of a preliminary nature and is being continued.

TABLE 1

Average Monthly Bacterial Counts in Dead Ends

DEAD END NUMBER	SIZE OF MAIN IN INCHES	COUNT PER MILLILITER BY MONTHS									
		July	August	September	October	November	December	January	February	March	April
At 37° Centigrade											
1	8	200	5,500	5,500	1,620	750	700	300	50	115	180
2	36	30	500	500	920	400	380	155	160	50	160
3	12	15	1,400	2,000	4,000	2,300	2,000	1,400	1,200	1,250	4,100
4	24	120	430	120	100	90	90	45	30	30	40
5	12	—	11,200	36,000	—	24,000	23,000	10,600	1,450	850	1,500
6	8	20,000	22,000	22,000	48,000	—	—	—	—	—	—
Plant Effluent	—	2	25	6	10	8	8	8	20	13	14
At 20° Centigrade											
1	8	580	6,000	6,000	2,700	2,700	2,500	2,000	5,500	1,460	2,300
2	36	900	3,500	3,500	1,900	1,800	1,500	5,200	1,800	240	920
3	12	40	2,500	4,000	10,200	7,900	7,500	2,100	1,900	2,230	4,800
4	24	150	1,000	1,400	1,700	3,400	5,300	4,200	950	590	860
5	12	—	12,600	37,000	—	26,800	25,500	13,000	5,000	7,500	5,000
6	8	80,000	54,000	54,000	71,800	—	—	—	—	—	—
Plant Effluent	—	8	130	120	25	150	120	20	90	17	53

It was found that the non-confirming spore forming organisms that occurred in the city water were aerobes and facultative anaerobes. One of the aerobes was identified as *Bacillus aerosporus*, another, a facultative anaerobe, *Bacillus asterosporus*, both of which fermented lactose broth with gas, while a non-lactose fermenter proved to be *Bacillus subtilis*. The pathogenicity of these soil organisms is not known, although they are believed to be harmless. This belief is

to be investigated, however, because of the number of sickness complaints that have been experienced during the short periods when these organisms are in relatively high concentration in the finished water.

A comparison of the bacteria present in the plant effluent and those obtained from the experimental dead end in the filter plant yard was made soon after its installation. Thirty-six colonies were picked from the dead-end plates and 24 were selected from the plant effluent plates. All the colonies were replated and repicked to ensure purity and were studied in detail under the microscope.

From the dead-end plates, 27 colonies were gram-positive rods of various sizes, whereas 4 were gram-positive coccus forms. From the plant effluent plates 16 colonies were gram-positive rods, while 7 were gram-positive coccus forms. Spores were observed in several rods, but no gram-negative organisms were present. When similar comparisons were made with samples from dead ends already existent in the distribution system, the same type of soil organisms, i.e. gram-positive rods, were present and, in addition, some gram-negative rods were found.

Numerous colonies of the gram-negative organisms were picked and subjected to study in a series of 16 different media, such a procedure being necessary to eliminate the duplicates and to identify the bacteria. After this study, nine separate species remained. One was a slow lactose fermenting organism, a member of the coliform group, *Aer. aerogenes;* another had all the characteristics of the coliform group, yet did not ferment lactose. Repeated transfer into lactose broth, however, induced gas production. According to Kligler's iron agar test, an organism was found that resembled the salmonella group. Since positive identification would have necessitated agglutination studies, however, no actual determination was made.

Summary

As stated before, all samples taken from the dead ends and from all sickness complaints have been subjected to the selective media technique for the isolation of the pathogenic enteric bacteria. Typical colonies that have survived this treatment are picked, purified and stored on an agar slant under sterile paraffin oil until there is sufficient time to study and identify them. To date, 137 colonies have been selected and 72 of them have been studied in detail,

microscopically and biochemically. It was found that ten of the colonies were gram-positive coccus forms; one, a gram-positive spore forming rod; 60, gram-negative rods of varying sizes; and one, a gram-negative coccus form. Dead Ends 3, 4 and 5 yielded 14 gram-negative colonies that were members of the coliform group (*Aer. aerogenes*), with indol negative, methyl red negative, Voges-Proskauer positive and citrate positive. Eight of these colonies were slow to produce gas in lactose broth and, hence, could be classified as slow lactose fermenters. After several transfers into lactose broth, however, gas production was produced much more readily. Two of the 60 gram-negative colonies from Dead End 2 were atypical coliform organisms, in that they were indol negative, methyl red positive, Voges-Proskauer positive and citrate positive. The remaining 56 colonies have been studied and their genus determined. Before a report is made, however, a serological study must be made.

Present Status of Investigation

Work Completed

1. Literature survey.
2. Development of an enrichment and selective media technique for the isolation of enteric pathogens.
3. The application of this method to all dead-end water and to that obtained from homes where complaints involving gastro-enteritis and other sickness have been received.
4. The selection of six suitable dead-end mains, and the design, installation and sterilization of a suitable sampling device on each.
5. Routine sampling of half the dead ends each week, recording temperature, determining the bacterial count on two media and the coliform content of the dead ends.
6. Application of the enrichment and selective media technique, favorable for the development of the pathogens, to all samples.
7. The selection, purification, classification, and identification of gram-negative bacteria. (The typhoid-dysentery-salmonella organisms are in this group.)
8. The study of the organisms in the plant effluent and the comparison of the organisms present with those found in the dead end. The identification and classification of the bacteria found. (The majority are gram-positive organisms.)
9. The isolation of species of slow lactose fermenting organisms of

the coliform group. (An organism, according to cultural characteristics and Kligler's iron agar resembled a member of the salmonella family, but antigenic studies would be necessary to verify this. Both slow lactose fermenting organisms and members of the salmonella family have been found in gastro-intestinal disorders.)

10. The isolation of three species of spore forming gram-positive organisms from the plant effluent and the dead ends. (These are most prevalent during the spring, when there appears to be an increase in the sickness complaints. The pathogenicity of these organisms is as yet unknown.)

11. The storage of 137 colonies, which survived the selective media technique, on agar slants under sterile paraffin oil for identification studies.

12. The detailed study of 72 of these colonies, both microscopically and biochemically. (Sixty were gram-negative rods, 1, a gram-negative coccus form, 10, gram-positive coccus forms and 1, a gram-positive spore forming rod. Fourteen of the gram-negative rods were the coliform organism *Aer. aerogenes*, and of these eight could be called slow lactose fermenters. Two of the gram-negative rods were atypical coliform organisms.)

Work Planned

1. The continued sampling of the dead ends, the recording of temperature and bacterial content, and the isolation, identification and classification of the gram-negative organisms, and, occasionally, of the gram-positive organisms.

2. The serological testing of all isolated strains of bacteria with known sera of the different known intestinal pathogens. (This is necessary to identify positively any suspected pathogens. Cross-agglutinations must be studied.)

3. The testing of the pathogenicity of the isolated organisms on suitable laboratory animals, orally and by injection.

4. Investigation of the presence of exotoxins in dead ends, using animals.

5. Determination of the effect of decomposition products, of bacteria and of the organic matter present in dead ends, using animals.

6. A study of the effect of large quantities of the gram-positive organisms, isolated from the dead ends, upon animals, based upon the fact that the ingestion of large numbers of apparently non-

pathogenic bacteria, even of dead organisms, is believed to cause gastro-intestinal disturbances.

7. Collaboration with the City Health Department, hospital laboratories and interested physicians to obtain organisms isolated from stool specimens of patients suffering from gastro-enteritis. (These organisms must have agglutinated the serum of the recovered patient in order to ensure that it was the causative organism. The injection of these bacteria into rabbits will produce sufficient sera so that the suspected pathogenic organisms isolated from the water supply can be tested serologically to determine if they are identical or related. This phase of the work is very important, for if these bacteria are identical, the gastro-enteritis can be considered water-borne.)

8. The determination of the chlorine resistant properties of the bacteria isolated in the distribution system and the chlorine residuals necessary for killing them.

9. The determination of whether or not chlorine and chlorine compounds have an irritating effect sufficient to cause gastro-intestinal disturbances.

In closing the authors wish to express their appreciation to L. G. Lenhardt, General Manager of the Detroit Department of Water Supply, for his instigation of this work and for the support that they have received from him and from the Detroit Board of Water Commissioners. Their continued interest in this work has made the study possible.

Protection of Utility Services in Wartime

By W. H. Wood and C. J. Pulham

The account which follows was recently received in this country by Wallace and Tiernan Co., Inc. It was prepared as a memorandum of information by W. H. Wood, General Manager and C. J. Pulham of the Technical Division of Wallace and Tiernan, Ltd., of London. When it came to the attention of the Editor, the value of the information contained was so evident that permission to publish it was immediately requested and granted. Its perusal will measurably improve the ability of water works operators to understand the problems to be met in times of war and air attack. The capacity of the British people to "carry on" urban life and activities in the face of such attacks deserves the highest admiration. Their courage is to be both commended and emulated.

Appreciation is due and expressed to the American and British Wallace and Tiernan organizations for their co-operation in making this information available.

THE supply of water, power and gas and the disposal of sewage have, in recent years, become universally available services, so commonplace that we have come to regard their continuity as assured as the air we breathe. Undoubtedly, therefore, a long-standing disruption of any of these services would have as great a moral effect, purely by reason of its absence, as the resultant physical effect. It is the fact that we can continue to eat and drink and travel after the heaviest raid which, undoubtedly, has caused observers to wonder at the normality and steadiness of the people who undergo such hardship. The bombing of our cities offends the eye and saddens the heart as we see the destruction of our most beautiful buildings, but such destruction has an aura of superficiality when the essentials of normal life can be maintained. Naturally, there are local and temporary interruptions in the service of gas, water and, sometimes, electric power, but the rapidity of their return reflects the highest praise on the authorities who are responsible for this work.

The maintenance of these services could not have been accomplished without foresight in planning and organization. Ideas and services have been pooled and experiences under "battle" conditions passed on, so that counter-measures everywhere have reached a high degree of efficiency. Some idea of these various schemes for maintenance of operation may be gathered from the following account, but the writer is naturally limited by space and by experience to general observations which will be more or less common to all cases and which will not take into account special precautionary measures adapted to varying local circumstances.

Defense of Water Utilities

In regard to water supply, the first essential, of course, is an accurately planned layout of the whole system, particularly with regard to location of valves, hydrants, bypasses, etc. According to the extent of the area for which the authority is responsible, the system is generally sub-divided into districts under the control of separate maintenance and repair teams, all in communication with a general headquarters from which reserves of men or materials can be supplied.

Normal communications cannot always be relied upon during or following an air raid. Therefore, the Metropolitan Water Board, which is responsible for the supplying of water to London and its suburbs, and probably other large authorities, provide motor cycle dispatch riders for each district. This service, which operates under normal as well as "battle" conditions, makes possible carrying reports and instructions and reports five or six times a day instead of by the much slower postal service.

Following the location of the various valves and other equipment, it is essential to make certain that they are all in proper working condition and that they are readily accessible. Positions should be altered if necessary, particularly where trunk mains are concerned, so that as little as possible excavation or shifting of debris will be necessary. Manufacturers have been of great assistance in this respect in providing fittings for the quick capping of the ends of broken mains, automatic self-closing valves, light sectional tubing, with flexible joints for connections across broken mains, and special collars for the repair of cracked pipes.

Immediately upon the report of damage to the distribution system, men are sent out from the nearest office to close the valves which isolate the fractured section of main. At the same time, wherever

possible, a manipulation of valves, whereby water can be bypassed from another section to maintain the supply in the locality affected by the damaged main, is carried out.

Although water consumption for domestic purposes is negligible at night, when most of the raids occur, it will be appreciated that wherever high explosives are falling, there are usually fires, and the water supply to all districts must be maintained, as far as possible, for fire fighting purposes. If a trunk main should receive a direct hit, for instance, it is not always possible to bypass the break quickly, so emergency supplies in large steel tanks, placed at strategic points in streets and squares have been provided for the use of fire fighters.

All information regarding the extent of damage is gathered quickly, so that all equipment likely to be required, and no more, may be dispatched to the scene. It will be appreciated that the damage is not usually confined to a single point and that after a severe night raid, such as is experienced in London, there is a widespread demand for repairs on the morning following. Where necessary, in such cases, reserves of men and materials are supplied from headquarters. Obviously, important or larger mains are dealt with first, and in the case of trunk mains, the continuity of supply may be obtained by connecting some of the special flexible tubing across the break, thus giving the repair squad an opportunity to carry out the necessary excavation and repair without interrupting the supply.

Fractured Mains

One of the greatest difficulties is to determine the extent of a fracture, because, apart from the obvious visual indications, the fracture is quite often carried some distance along the main, necessitating fairly extensive excavation. Again, vibration may give rise to a leak or fracture which will give no material evidence of its location. To guard against pollution as the result of such hidden fractures, it is generally the practice to maintain a much higher (about 1 p.p.m.) chlorine residual than normal, to the consumers in towns subject to frequent raids. After the repairs, of course, the mains are sterilized, and, in this connection, manufacturers have been quick to meet the demand for portable equipment.

Generally speaking, the consequences of damage to a main pumping station may be met by duplication of plant and by an arrangement of bypassing whereby each station can supply some other than its

own particular area. One excellent scheme covers the provision of portable boilers and pumping equipment, situated at such a distance from the main pumping station as not to be damaged with the latter. Thus, if the main engine house should be put out of action, a portable pump can be brought into use.

Sterilization Practice

The Ministry of Health has taken the initiative in instructing all authorities responsible for supplying water to communities of more than 1,000 population to install chlorinating equipment, such equipment to be capable of applying a rate of treatment of 1 p.p.m. to the maximum flow. Generally speaking, existing chlorinating plants have been adapted or alternative capacity metering apparatus has been provided to give such a rate of treatment for cases of emergency. Normally, the average rate of treatment of chlorine applied to a domestic water is very much lower in Britain than in the United States, being usually from 0.15 to 0.5 p.p.m.

It will be appreciated that circumstances may arise whereby the normal available operating pressure for the injector of the chlorinator cannot be obtained, and provision must be made so that sterilizing treatment may be continued with a low water pressure. Such measures will probably be of greater importance in the U. S., where high pressures are common and readily available. Even under peacetime conditions in Britain, it is very frequently necessary to supply a booster pump to give a pressure water supply to operate a chlorinator.

Apart from their individual organization to meet the consequences of air raid damage, water authorities have formed themselves into various pools throughout the country, not only to assist each other in maintaining a water supply to a damaged area, but also to purchase, as a pool, such equipment as may be deemed necessary to meet their needs, the equipment being held at the disposal of any of the members of the pool, and the cost being borne proportionately by them all.

Contamination by Enemy Action

There has also loomed rather large in the mind of the general public, the question of what would happen to the water supply if poison gas or bacteria were introduced into the reservoirs. The danger from this method of attack, however, is not very great, because it would

require far more poison gas or bacteria than it would be practical to apply to overload existing purification plants, if they are efficient. Tests on the solubility and hydrolysis of mustard gas have shown that saturated aqueous solutions contain 0.7 gram of gas per liter at 10°C. and 0.8 gram at 15°C. These concentrations were completely hydrolyzed after two hours.

Further tests, carried out by contaminating sand filters in the proportion of 2 cu.ft. of mustard gas to 10 sq.ft. of area, indicated that, with a vertical filtering speed of approximately 10 ft. per hr., direct contamination was completely held back by the sand, generally in the surface layers, and the filtrate was freed of all contamination after a run of 14 hr. The presence of algae on a filter tends to hold the mustard gas rather longer, although with no apparent immediate detriment to the survival of the algae. With algae present, mustard gas was detected in the filtrate for 60 hr.

Tests with chlorine were carried out on a saturated solution of mustard gas and it was found that an addition of chlorine equal to half the amount of mustard gas completely freed the solution from contamination after 12 hr. Presumably the same rule would apply for lower concentrations of mustard gas, i.e., it may be effectively countered by the addition of chlorine in quantities equivalent to half the concentration of the mustard gas.

Activated carbon, in the rather higher proportion of approximately five-eighths the quantity of mustard gas, also effected decontamination.

These tests confirm the contention that the usual purification plants, including sand filters, render mustard-gas-contaminated water practically free from danger, any residual in the filtrate disappearing within a few hours, or being eliminated by application of proper chemical treatment.

Defense of Sewage Works

The sewage authorities problem is not so different from that of the water authorities, with the one important exception that they act as disposers while the water authorities are suppliers. The implications of this distinction will be obvious.

Continuity of disposal, however, is most important, and most disposal works were already equipped (as standard practice) with arrangements for bypassing. Where a fracture occurs in the mains

conveying the sewage to the works, the general practice is to connect across the fractured and isolated section with flexible tubing, while repairs are effected; but in the case of large trunk mains, this is not always possible. A system of "overflows", whereby the sewage is conveyed from the site of the fracture to the nearest watercourse, has been adopted widely. Chlorinators have been supplied to sewage authorities so that the crude sewage may be treated before being discharged into a watercourse, but this is not yet general practice.

The system of "overflows" was developed before the danger of air raids became immediate, and, in brief, consists of the insertion of a penstock in the sewer, on the downstream side of a manhole. From the manhole a pipe is laid to a nearby watercourse. In the event of damage to a section of the main, the penstock on the upstream side of the fracture is immediately closed, and the sewage overflows through the pipe in the manhole to the adjacent watercourse. Automatic valves can be placed in the overflow pipes, designed to open with a rising sewage level. To save a fraction of time, the penstocks are closed by the operation of a trip which immediately frees the brake on the windlass, allowing the penstock to fall by its own weight. A number of these overflows were already in use as part of a sewage works disposal scheme to take care of storm water.

Defense of Gas Utilities

The coal gas companies have probably the most difficult of problems, but, from the public's viewpoint, a temporary interruption in the supply of gas, although most inconvenient, is not vital, because cooking can be carried on with coal fires or electric power. Communal feeding centers are a great help and the spirit of neighborliness among the people solves many problems. As long as water is available for boiling, either over a fire or by an electric heater, food can be prepared adequately to meet immediate needs.

The greatest problem the gas companies have to face arises from the fact that the broken gas mains frequently fill up with water, which must be pumped out before repairs can be made effective. At the gas works, the holders are either emptied or held partly filled during a raid; and, because of their construction, a hit on a gasometer does not result in an explosion but in a fire, the proportions of which depend upon the size of the fracture. Already men have won "George" medals for bravery in scaling flaming gas holders to seal up holes

through which the gas is escaping and burning. As you will, of course, know, coal gas will ignite only in the presence of air, and explodes only when the admixture with air has reached a definite proportion.

Wherever damage to a gas main occurs as the result of a bomb, the escaping gas is usually fired, and quick action is required as a countermeasure. As with the water authorities, the gas companies have organized their various squads for immediate action, and the fire is put out and the fracture in the main temporarily repaired by members of a team wearing asbestos suits, who ram or plug the broken end, using a long-handled ram rather like those used for muzzle loading old fashioned guns. It will be appreciated that considerable force must be used to get the gas-tight plugs inserted well down into the main. Often a team of three or four men must grasp the handle of the ram and charge from a distance in order to get momentum. As in the case of the water, however, supplies are maintained wherever possible by a system of bypassing.

Electric and Telephone Service

Mainly because of the excellent grid system, interruptions in the supply of electricity are rare and of short duration. The grid system provides for almost unlimited bypassing, while the power stations are generally protected by the multiplication of plant.

In view of its importance in providing quick communication, perhaps a few words should be included regarding telephone service. As you may know, the country is divided into a number of small areas, in each of which is an "Exchange" making connection to subscribers in its area. These exchanges are themselves inter-connected by what might be termed "main" lines. If a subscriber in "A" exchange area wishes to call a subscriber in "B" area, he is first connected to his own exchange and through them to "B" exchange, where the particular number desired is selected. This, of course, is done more or less automatically. If, following a raid, the main lines of communication between one exchange and another are broken, a system of bypassing is adopted. Taking the example given above, direct communication between the two exchanges is broken, the "A" exchange will get in touch with "C," "D" or "E" exchanges until one is found which is still connected to "B," contact is then made through them. This, of course, results in considerable congestion at certain exchanges, and to avoid it, only "priority" calls, for military or civil defense purposes, are accepted, until repairs can be effected.

Summary

Summarizing, therefore, the main requirements of an efficient air raid precautions organization for a public utility service are the organization of A.R.P. squads thoroughly conversant with the area for which they are responsible; provision of bypass facilities, adequate stocks of materials for reparation of damage and, where applicable, necessary treatment; and duplication of essential plant. Incidental safety measures are, of course, the sandbagging and protection as far as possible of vital buildings, protection against direct enemy activity or sabotage, which is provided for by the Home Guard, and by the exercise of imagination. Imagination will show the measures necessary for "defense in depth," the responsible organization being prepared to meet the possibility of the first counter-measure's being nullified, likewise the second, and perhaps also the third. Finally, and perhaps there is no need to add this, the most important part of the equipment of an efficient A.R.P. organization is courage.

ABSTRACTS OF WATER WORKS LITERATURE

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STERILIZATION

Influence of Electrolytic Processes on Development of Chemical Industries. COLIN G. FINK. Am. Chem. Soc.—News Ed. **19:** 193 (Feb. 25, '41). First American electrolytic alkali-chlorine plant built at Rumford Falls, Me., in 1892. Mathieson Alkali Works at Saltville, Va., installed first Castner mercury cells in 1895 and soon after moved to Niagara Falls. Now 50 plants mfr. electrolytic chlorine in 20 states. Report of Federal Power Com. states that mfr. of electrolytic chlorine requires about 40% of total electrolytic energy used in U. S., and is third largest consumer of electricity in process industries, using over 2 billion kw.hr. per yr., or if calculated at 0.5¢ per kw.hr., $10,000,000 per yr. In 1890, practically all chlorine made converted into bleaching powder, but now less than ½ so used. Over ½ of chlorine used in mfr. of organic chemicals. Sterilization of drinking water and of sewage has developed into separate industry of great national importance. Liquid chlorine today is shipped in tank cars holding 30 tons or more. Annual production, 500,000 tons. Numerous other electrolytic processes discussed.—*Selma Gottlieb.*

Water Sterilization: The Choice of Method. E. F. W. MACKENZIE. Surveyor. (Br.) **98:** 277, 291 (Nov. 29, Dec. 6, '40). If supply adequately protected from source to consumer's premises, strong arguments against application of any process of sterilization exist. Addition of chemical sterilizing agent may engender false sense of security. Processes in common use, aside from treatment by excess lime, for chem. sterilization of water supplies include: simple chlorination, chloramination, super-chlorination, and ozonization. In simple chlorination only 1 chemical is added. Size of most suitable dose constitutes important problem. In case of ammonia-chlorine process, sterilizing agent is comparatively stable and may persist for several days. Germicidal effect, when applied to different waters, or to same water under different conditions, varies over wide range. Taste-preventing properties of ammonia permit increase in dose of chlorine sufficient to counteract slower action of resultant chloramine. In case of many waters, long contact may be necessary to ensure elimination of *Esch. coli.* Need for adequate contact is too long neglected. In Britain usual to apply term super-chlorination somewhat loosely to application of chlorine in a dose considerably in excess of that necessary for adequate bacterial purif. of a water. In America, use of term is restricted to application in dose sufficient to bring about more or less complete oxidation of all organic matter in water. De-chlorination is most conveniently performed by means of sulfur dioxide gas. Super-chlorina-

tion followed by de-chlorination by passage of water through carbon filter may well be considered separate process. Powdered activated carbon appears to have been used for removal of tastes and odors from drinking water by firm in Amsterdam shortly after last war. Some years later Imhoff experimented on removal of tastes from water supply to city of Ham by filtering it through granular activated carbon. Similar plant installed in Dresden in '30. Success of activated carbon in removing tastes was rapidly followed by its employment as de-chlorinating agent. Ozone exerts purifying action rapidly and may, therefore, be removed almost immediately. Effects of ozone on water are destruction of all harmful bacteria, removal or reduction of color, odor, and taste, and oxidation of organic matter. Is at least equal to super-chlorination as regards bactericidal power. First used for purif. of water at Metz in 1840. Used now in France, Russia, Italy and U. S. Salient points of each process summarized as follows: simple chlorination capable of producing water of good bact. quality but only if sufficient contact time is available; chloramination offers possible advantage of providing residual sterilizing agent in supply system; ozonization and super-chlorination can be relied on to produce water of high bact. purity without imparting a taste. Two arguments may be used against policy of passing residual chlorine into supply: (1) consumers object to drinking water which contains "chemicals"; and (2) difficult to regulate dose to changes in pumping rate. At some time every water supply administrator faced with decision upon most suitable means of purifying supply. Recently such a decision was required for wells which draw water from chalk which outcrops in North Downs to south. Water, although somewhat hard, is of excellent quality and contains little organic matter. Choice lay between ozonization and super-chlorination. Latter was chosen and proved eminently satisfactory. *Discussion. Ibid.* **99:** 107, 244 (Feb. 7, Apr. 4, '41). DAVID M. WATSON: Prevention of pollution of potable water better than its cure. Nevertheless we shall never reach such stage of perfection that sterilization unnecessary. W. J. E. BINNIE: Writer would draw attention to two methods of purif. which have not hitherto received attention they deserve, i.e., use of activated carbon and ozonization. Description of granular carbon filters given (by author) of great interest, as here filters serve dual purpose of de-chlorination and removal of taste due to other causes than chlorine. Turning now to ozonization: writer visited plant installed at Petrograd where he was informed that after water had been sterilized, it was pumped into service reservoir where it became mixed with polluted water—typically Russian procedure. Not necessary that water (to be ozonized) be free from particles in suspension. Objections put forward to sterilization by ozone financial. Process has, however, been adopted by several towns and has been stated that cost of sterilization by ozone amounted to about 14s. 5d per mil.gal. (Imp.). JOHN BOWMAN: Comparing simple chlorination and chloramination, chief objection to latter, that retarding influence of ammonia may seriously interfere with sterilization unless long contact possible. Application of ozone always seemed to writer to be method (of sterilization) most attractive. One reason that ozone not been considered more widely is that system more costly of application. JOHN T. CALVERT. One aspect of chlorination to which Mackenzie has not drawn attention, i.e. universal chlorination of supplies as war precautionary measure to guard against possibility of contamination due to burst mains. When pure water regularly obtained, appears to me unnecessary to adopt continuous chlorination. A. P. I. COTTERELL: System comprising super-chlorination and de-chlorination presents undoubted advantages, both as regards safety and palatability of treated water, and ease and flexibility of working conditions. Ammoniation with super-chlorination and partial de-chlorination form another combination sometimes successful. Ozonization presents many attractions as normal form of water treatment and sterilization. R. C. S. WALTERS: Thor-

oughly endorse that "first line of defense" must be clearing up all sources of contamination of gathering ground. Since Croydon case, examinations of water supplies have been tightened up and are made much more frequently with most illuminating results. *Author's Closure:* Pleasing feature of discussion is unanimity with regard to desirability of conserving original purity as opposed to counteracting pollution by chemical means. At present unable to say whether concentration of ozone required to sterilize increased by presence of particulate matter *per se*. Any tendency to rely solely upon residual chlorine for sterilization of mains to be deprecated. Reassuring to note from daily press that advice being given to boil all drinking water. May not be practicable to comply with this advice and it is matter for consideration whether it would not be better to issue tablets of high titre chlorine preparation and sodium thiosulfate, which are in use by army for emergency sterilization. Author's opinion that introduction of coliform organisms, but not of *Esch. coli*, in service reservoir need be regarded as indicating probability of dangerous pollution only if condition of reservoir such that coliform organisms may be the forerunners of *Esch. coli*. Several cases encountered in which coliform organisms other than *Esch. coli* Type I have flourished in situations in which they could not be regarded as indicators of fecal pollution. A. SCIVER: (discussion submitted subsequent to Author's Closure). With regard to tastes arising from some waters on chlorination, not at all sure that we have yet arrived at final explanation. Usually custom to ascribe these tastes to chlorophenols. May be all a question of organic content of water. Experience tends to indicate that organic matter in solution has to be "satisfied" with chlorine before latter available for bactericidal action. Enthusiastic on treatment of water by ozone. Only serious objection to its use at moment, that it leaves no residual in system. Appears practically instantaneous in action. Not enough attention yet been paid to optimum production of ozone by control of humidity of air, voltage on electrodes, velocity of air through tubes, etc. In sterilization of water mains with chlorine, necessary to use several parts per hundred thousand with contact period of 24 hr. or more. *Author's Comment:* Do not share Sciver's anxiety over dangers of negligence in operating ozone plants. Recognized that methods used as wartime measure for sterilization of mains by no means perfect.—*H. E. Babbitt.*

Ozone Sterilization in Municipal Water Works at Groningen. J. HAMMACHER. Water. (Neth.) **25:** 53 (Apr. 4, '41). Plant treats mixed surface and well water by filtration. Chlorination rejected because of taste. Ozone obtained by electric current at 7,000 v. and high frequency (467 cycles) passing through dry air. For drying of air, silica-gel installation chosen over chloride of lime to prevent freezing. Gel present in 2 absorbers, used alternately. While one used, other reactivated by hot air supplied by oil heater, entirely automatic. Although at 15°C. relative humidity of 20% allowed, lower figures obtained. Dry air sucked through ozonators by means of water-ring compressors of stainless steel. Each ozonator contains 60 stainless steel electrodes, mounted in glass tubes surrounded by cooling water. Air passes between electrodes and glass and current passes through air and glass into water, which acts as ground. With energy development of about 9.2 kv.-amp. per 200 cu.m. air per hr., 2.5 grams ozone per cu.m. air developed. 1 cu.m. air required for 2 cu.m. water. Energy developed by generators, 300 v., 467 cycles; boosted to 700 v. by transformer. Ozonized air passes to 3 injectors and rapidly mixed with water; mixture passes vertical reaction tube 6½ m. long, thence to sterilization cylinders. Velocity in tube 2 m. per sec.; contact time of 3 sec. usually sufficient for sterilization. Sterilization cylinders 3 m. in diam. and 7 m. high, allowing 8 min. contact time. All machines and pumps driven by diesel motors of 44 h.p., via central axis 23 m. long. Machines connected with friction couplings; 4 motors run parallel on axis, not tried before. Installation developed into 4 groups corresponding to 400 cu.m. per hr. No increase in personnel; all

automatic. Controls are: oil pressure diesel motor, cooling water temp. diesel, axis, high voltage, drying installation, air velocity (for protection of ozonators), pressure, motors in operation, presence of ozone under sterilization cylinders after passing of reaction tubes, attention signal when moisture content of air is max. allowable, same when limit has been passed. Each machine has its own signal, shown in central machine room about 200 m. away from sterilization bldg. Installation demands for production of 1 gram ozone about 1 v.-amp. at generator, or 15 w., as compared with usual 16 to 20 w. Ordinary, cheap thick calcium glass used for electrode tubes. Proper mixing of ozonized air with water important because of rapid decomposition (max. 10 min.) of ozone. Various mixing devices insufficient; injectors (of concrete with stainless steel nozzles) allow water and air mixing to produce almost an emulsion. Used air containing 0.5 gram ozone per cu.m. cannot be re-used. Testing with KI and starch for ozone also automatic.—*Willem Rudolfs.*

Ultra-Violet Irradiation Water Sterilizer. ANON. Ann. Lavori Pub. (Rome) **77**: 1185 (Nov. '39). Small-scale apparatus that has won wide acceptance in hygienic, industrial, and medical circles described and illustrated. All forms of bacterial, protozoal, and fermentative organisms destroyed by it. 700-watt mercury vapor arc lamp in quartz tube, 20 mm. in diam. and 178 mm. long, central axis of cylindrical sterilizer. Airspace intervenes between lamp and second quartz cylinder of 51 mm. internal diam., which is interior surface of water space. Exterior is brass cylinder of 102 mm. external diam., chromium plated inside, and with small glass observation window, about half-way up, through which no ultra-violet radiation can escape. Water-space, through which water is given spiral path, <1.5 liters. At max. flow-rate, of about 0.75 liter per sec., every portion of water receives 1.75 sec. exposure to radiation; by reducing rate of flow, time of exposure can be proportionately increased; thus, when flow cut down to 0.13 liter per second, exposure becomes 10 sec., and corresponding rise in temp., 5°C. When lamp first turned on, delay of 3 min. should be allowed before turning on water, so that lamp may attain normal intensity. Life of tube about 1,000 hr. Constancy of emission secured by stabilizing rheostat. Automatic model offered in which flow of water utilized to switch on current.—*Frank Hannan.*

Rapid Methods for Chemical Sterilization of Drinking Water. R. NEVEU. Presse Med. (Fr.) No. 88–89:1581 ('39); Lab. Prakt. (U.S.S.R.) **15**: 7–8:14 ('40). (1) Add 0.02 gram of $Ca(ClO)_2$ per liter of water and sterilize for 30 min.; milky color of water requires further filtration and water unpleasant to taste. (2) Br in amts. of 0.06 gram per liter sterilizes water perfectly, but is hazardous to health and is, therefore, not recommended. (3) I in 1:100,000 ratio destroys all microbes in 15 min. Simpler to use Lugol soln. adding it to water until slightly yellow color obtained, which is destroyed (after 20 min.) with NaClO (1 drop per liter). (4) Add $KMnO_4$ to water until slight pink color obtained. After 20 min. remove excess $KMnO_4$ by alum or hypochlorite. (5) Wells with contaminated water are pumped out and washed with freshly slaked lime (10 kg. of lime is slaked by mixing with 40 liters of water). Or a mixture consisting of $KMnO_4$ 5 grams + $KAl(SO_4)_2$ 50 grams + water 10 liters per cu.m. of well is added to well. Water for drinking cannot be taken before 2–3 hr.—*C. A.*

A Study of the Methods of Measuring Germicidal Efficiency of Chlorine With Reference to the Oxidation-Reduction Potential, Starch-Iodide Titration and Ortho-tolidine Titration. W. L. MALLMANN AND WILLIAM B. ARDREY. Mich. Eng. Expt. Sta., Bul. 91 (Nov. '40). Study undertaken because of relative lack of data on significance of available chlorine in terms of germicidal effectiveness, particularly in solns. containing organic matter. Use of potentiometric methods in detn. of germicidal efficiency should be possible since in disinfection process, shift from positive to negative charge in Cl ion always takes place regardless of whether nascent O, nascent

Cl or HOCl theory accepted. Detn. of oxidation-reduction potentials of chlorine (NaOCl) treated distilled water after 15 min. contact with doses from 0 to 1.27 p.p.m. Cl_2 indicated gradual constant rise in voltage with increasing Cl dosage until residual reached approx. 0.9 to 1.10 p.p.m., when sharp rise occurred with each additional dose. This rise sharper in alkaline range than in acid, existed in solns. with pH values between 5.0 and 9.0 (limits of test), actual voltage reading lower at higher pH. Relationship between oxidation-reduction potential and speed of disinfection detd. with NaOCl concs. up to 1.5 p.p.m. in distilled water, solns. standing 30 min. before addition of 1 ml. of standard suspension of *Esch. coli* organisms. Bacteria remaining after 15, 30, 45, 60, 90, 120 and 180 sec. detd. Evident from data obtained distinct relationship exists between oxidation-reduction potential of Cl soln. and its germicidal action, especially apparent at pH 7.0 and 9.0 and particularly evident in 15 and 30 sec. contact. Curves show constant gradual increase in potential and percentage reduction of bacteria, with sudden increase at higher Cl conc. (0.7–1.1 p.p.m. approx.). Sharp rise not evident in longer contact periods because with additional time all or most of bacteria have been killed by Cl conc. existing at start. Indicated oxidation-reduction potential accurate measure of immediately available Cl and gives information not shown by starch-iodide and ortho-tolidine. In tests with organic matter present, 0.1% amounts of agar were used, agar used as representative type of insoluble organic matter. Cl added to obtain desired residuals ranging from 0 to 4.90 p.p.m., in steps of 0.70 p.p.m. solns., allowed to stand 24 hr. to allow set-up of equilibrium, residual detd., and speed of disinfection at pH 5.0, 7.0 and 9.0 then observed. Tests probably not simulated often in actual practice. In all cases addition of successive amounts of Cl resulted first in increase, then marked decrease, followed by second increase in chlorine residual. Starch-iodide and ortho-tolidine curves followed generally by potential curve, except latter curve gives truer indication of what might be expected with various Cl concs. Comparison made of germicidal activity of Cl-treated water with and without agar present. At each pH, noted that instances occur where Cl-agar combination actually more germicidal than Cl solns. alone, although titratable points comparable. More active points always on second increase curve. In tests with soluble organic compd. (0.01% Peptone) correlation again shown between oxidation-reduction potential and germicidal activity, and no relationship with titratable Cl (residual by ordinary tests). When Cl added to unstabilized solns. (1 ml. *Esch. coli* in 500 ml. distilled H_2O with organic matter both suspended and in soln.; Cl-soln. added and bacterial reduction detd. at end of 15, 30, 45 etc., up to 180 sec. contact), no rise and fall in titratable Cl but steadily increasing residual Cl content found; voltage curve also steadily increased. Bacterial kill rose steeply at first and then leveled off. Among conclusions, authors state: (1) oxidation-reduction potential gave accurate indication of relative concentrations of germicidal action which may be expected between different concentrations of chlorine (NaOCl) both in presence and absence of organic matter; (2) neither starch-iodide nor ortho-tolidine titrations gave accurate indication of relative amts. of germicidal action between different concs. of chlorine (NaOCl) either in presence or absence of organic matter; (3) little or no correlation exists between starch-iodide and ortho-tolidine tests when organic matter present; (4) Cl-demand of solns. with organic matter higher by ortho-tolidine than by starch-iodide; (5) with solns. containing identical amts. of chlorine (NaOCl) at different pH values, oxidation-reduction potentials indicate increased germicidal activity with increasing acidity, whereas starch-iodide and ortho-tolidine titrations gave same values at different pH values; (6) with addition of increasing amts. of chlorine (NaOCl) to solns. containing agar, point was reached where agar exerts increased germicidal effect over that of solns. containing same amts. of titratable chlorine but in absence of agar.—*Martin E. Flentje.*

The Effect of H-ion Concentration and of Ammonia on the Germicidal Efficiency of Chlorine. GEORGE R. WEBER AND MAX LEVINE. (*Published in abstract only.*) J. Bact. **41**: 89 (Jan. '41). Relative germicidal efficiencies of chlorine (Cl_2), and of Cl_2 to which various concentrations (concs.) of ammonia (NH_3) had been added, determined by ascertaining time required to kill 99% *Bacillus metiens* spores exposed to approx. 25 p.p.m. available Cl_2 at 20°C. and at various H-ion concs. (pH) 5-10. Efficiency of disinfection increased with increasing pH when Cl_2 employed alone. Killing times of 2.1, 2.3, 3.0, 7.6, 58 and 570 min. observed at reactions pH, 5, 6, 7, 8, 9, 10, respectively. Chloramine solns. (1 p.p.m. NH_3 for each 4 p.p.m. available Cl_2) showed no significant differences in germicidal efficiency at pH 6, 7, and 8, respective killing times being 85, 89, and 83 min. At pH 5, however, killing time increased to 168 min., and at pH 9 and 10, rose to 182 and 186 min., respectively. With larger quantities of NH_3 (3 p.p.m. NH_3 to 4 p.p.m. available Cl_2) max. germicidal efficiency observed at pH 6, with killing time of only 59 min. At pH 5, rose to 99 min., and at pH 7, 8, 9, and 10, increased to 84, 107, 263, and 456 min., respectively. Cl_2 more effective germicide than NH_2Cl_2 solns. at reactions more acid than pH 9.3, whereas at more alkaline reactions, latter more efficient.—*Ralph E. Noble.*

Chlorine in Public and Domestic Sanitation. S. H. WELLINGTON. Dept. of Pub. Health, Victoria, Australia, Health Bul. **61** and **62**: 1730 (Jan.-June '40). In reviewing virtues and limitations of chlorine, immediately evident that virtues many and limitations few. Chief limitation as sterilizing agent lies in sensitivity to presence of organic matter, but, in many cases, objection can be overcome either by super-chlorination or by chloramination, and only in rare cases is use ruled out by restriction. On other hand, for purpose of killing intestinal organisms, it is unsurpassed. Effective in very minute quantities, rapid in action, unobjectionable and non-poisonous in quantities used, and non-corrosive to plant and utensils when used correctly. Method of application simple and non-critical, being capable of wide latitude. Strong deodorant and one of cheapest and most effective antiseptics on market. Doubtful, indeed, whether any other chemical has done so much to conserve public health throughout world.—*P. H. E. A.*

Some Practical Applications of Chlorine Compounds as Disinfectants. F. A. ST. HILL. Dept. of Pub. Health, Victoria, Australia, Health Bul. **61** and **62**: 1732 (Jan.-June '40). Time is essential factor in obtaining efficient sterilization. Small amt. of disinfectant acting for several hours will produce sterilization equal to that obtained by using large proportion of disinfectant for few min. Commercial chloride of lime marketed in several grades, e.g., one contains 35% available chlorine, another 70-75%. Liquid sodium hypochlorite (usually 10% available chlorine strength) also marketed in large quantities. Certain precautions should be taken when using chloride of lime. It is strong bleaching agent, and solns. should not be allowed to come in contact with colored fabrics or upholstery or with human hair. When used to clean lavatories or sinks, etc., soln. should be followed by good flush of water down waste pipe. If this is done, plumbing will not be affected.—*P. H. E. A.*

The Sterilizing Quality of Chlorine Solutions Under Different Conditions. F. M. SCALES AND M. KEMP. J. Milk Tech. **2**: 215 ('39). Describes investigation into conditions under which greatest germicidal action of chlorine can be obtained. Chlorine in acid soln. is more powerful oxidizing agent than chlorine in alkaline soln.; as destruction of organisms by chlorine is oxidizing process (formation of chloramine with amino acids of proteins in cells), hypochlorite should be more strongly bactericidal in acid than in alkaline soln. Acid solns. less stable than alkaline solns. In expts. to determine effect of temp. on content of chlorine, solns. containing 53.4 p.p.m. available chlorine and adjusted to pH 6 and pH 11, were

maintained for 30 min. at temps. of 50° and 90° F.; at 90° F. soln. with pH value of 6 lost only 0.87 p.p.m. chlorine; no chlorine was lost from the other solutions. Tests made of action of solns. containing 50 p.p.m. available chlorine, with pH values of 6, 7, 8 and 11 and at temps. of 50°, 60°, 70°, 80°, and 90° F., on *Staphylococcus aureus* and on mixed culture from surface growth on milk. Sterility obtained more rapidly at pH 6 or 7 than in more alkaline solutions; results were less satisfactory at 50° F. than at higher temps. and were slightly better at 80° and 90° than at 60° and 70° F. Further expts. showed that at pH 6, soln. containing 50 p.p.m. chlorine destroyed over 99.9% of *S. aureus* in 3 min. Soln. containing 255 p.p.m. chlorine at pH 9.5 destroyed 37.5% of spores of *B. subtilis* in 3 min.; at pH 6 soln. containing 50 p.p.m. destroyed 71.9% in 3 min. and 99.89% in 5 min. Chlorine solns. used for spraying generally contain 255 p.p.m. chlorine and solns. for circulating in equipment contain 105 p.p.m.; both are generally prepared by dilution of stock solutions containing 15% chlorine. These stock solns. are generally strongly alkaline as they are more stable in this condition. Tests by spraying on portions of steel storage tank indicated that a spray containing 50 p.p.m. available chlorine and with pH value of about 6 was as effective in 3 min. as spray containing 255 p.p.m. chlorine and with pH value of about 10. Addition of acid sodium phosphate found to be satisfactory method of obtaining required acid reaction. —*W. P. R.*

Chlorination as a Method for the Purification of Waste Waters. V. E. Kuni and M. N. Platonova. Vodosnabzhenie Sanit Tekh. (U.S.S.R.) **9:** 64 (37); Khim Referat Zhur. (U.S.S.R.) **6:** 81 (38). In purification of waste waters of textile mills, doses of 395–450 mg. per liter caused a rapid coagulation and pptn. of all suspended and of part of dissolved org. substances. Physical properties of water improved after filtration through paper or sand. Approx. 30% of Cl remained unused. As result of chlorination, amt. of the pptd. substances reached 17.6 mg. per liter; approx. ⅓ of org. substances contained in water were removed.—*C. A.*

Break-Point Chlorination. M. S. Campbell. Water Supply & Sew. News. **4:** 2 (Nov.–Dec. '40). Comprehensive discussion of break-point chlorination, development, and practical application for disinfection and odor control on water supplies. 4 typical curves obtained when chlorine residuals plotted against chlorine dosages with different types of water shown. Portion of discussion devoted to explanation of certain apparent inconsistencies in residual-chlorine control, as very often observed by operators. Specific example in State of Washington in which operator found that he was unable to increase chlorine residual when application rate increased from 30 lb. of chlorine to 100 lb. per 24 hr. cited. Reason fully explained in light of available knowledge of break-point chlorination.—*P. H. E. A.*

Attempted Sterilization of Sewage Works Effluents by Means of Chlorine. E. G. White. Pub. Health (So. Africa), p. 2. (Feb. '40). Describes experiments carried out at Cydna lab., Johannesburg, to determine amt. of chlorine which must be added to effluents from different Johannesburg sewage works to ensure presence of 0.1 p.p.m. chlorine after different times of contact, to examine disinfecting action of adding sufficient chlorine to satisfy this chlorine demand, and to determine amount of chlorine required for complete sterilization of effluent. Addition of up to 5 times the quantity of chlorine required to leave 0.1 p.p.m. after 10 min. did not sterilize effluents; number of bacterial colonies growing in nutrient agar were reduced by longer contact periods and chlorine demands were increased, but coliform organisms were present in 10 ml. until the contact period was increased to 4–6 hr.; few samples were completely sterile even after 24-hr. contact. Addn. of ammonia with chlorine reduced amount of chlorine absorbed; total bacterial count was increased. The higher the ratio of

ammonia to chlorine, the slower was sterilization. Lowering pH of effluents by adding acid increased chlorine demand and gave more rapid disinfection. Treatment with alum and with alum and lime, followed by filtration, reduced chlorine demand. In discussion various speakers dealt with methods of reducing chlorine demand of sewage works effluents. These included irrigation, cascading, and treatment with potassium permanganate, catadyn, ozone, and ultra-violet light. Pointed out that effluents discharged into streams should not contain free chlorine. Communication from eng. co. deals with action of nitrites and ammonia in sewage works effluents in interfering with action of chlorine. Chlorine is generally applied to sewage for purpose of preventing it from becoming septic, or of removing hydrogen sulfide, or of preventing odor nuisance. For these purposes, not necessary to add sufficient chlorine to satisfy full demand. Insufficient mixing is often cause of unsatisfactory results from chlorination.—*B. H.*

The Sterilization of Water by Combinations of Ammonia and Chlorine. R. BUYDENS. J. Pharm. Belg. (Belg.) **21:** 1043 ('39). Addn. of NH_3 and Cl separately to water gives quicker sterilizing action than addn. of a premixed soln. of agents. Faster action is attributed to presence of greater concn. of HOCl in water being treated. Also explains slower sterilizing action of chloramine derivatives. When undesirable odors or tastes are present, NH_3 should be added before Cl.—*C. A.*

Free Ammonia in the Presence of Chloramine. E. E. WOLFE. W. W. & Sew. **86:** 509 (Dec. '39). Overdosage of ammonia may allow production of nitrites, requiring excessive chlorine doses. Mississippi R. water at Hannibal, Mo., has heavy chlorine demand, which pre-ammoniation intensifies. Nessler test proves unreliable for measuring uncombined ammonia in presence of chloramine. Author finds combination of McNamee's method for measuring combined ammonia in monochloramine, and Folin's method for measuring ammonia, gives good results. McNamee suggested acidifying sample to pH under 4.4 to convert to NCl_3 for Nesslerization. Folin employs synthetic zeolite for NH_3 absorption, and author finds this zeolite does not take NH_3 from chloramines. Test used to keep excess ammonia to minimum in plant.—*H. E. Hudson, Jr.*

The Hypochlorites of Calcium of High Titer and Their Preservation. A. GUILLAUME AND Y. NICOLAS. Ann. Chim. Anal. Chim. Appl. (Fr.) **21:** 261 ('39). In France, bleaching powder is evaluated in terms of Gay-Lussac degrees, which represent liters of chlorine obtainable from 2 kg. of powder. 4 French supply houses furnish "chloride of lime" equiv. to 220° under names, Jav, Chlorfix, Perchlorfix and Perfix. Expts. showed bleaching powder of 220° has excellent keeping qualities in unlighted ice chest and is much more stable under all conditions than ordinary bleaching powder. 3 methods of iodometric titration were employed: (1) treatment with KI and AcOH, followed by titration with $Na_2S_2O_3$; (2) treatment with HCl in place of AcOH; and (3) substitution of $KHCO_3$ for acid. Pontius method, which uses $NaHCO_3$, gives somewhat higher values than are obtained when HCl is used and results are a little higher with HCl than with AcOH, but difference rarely exceeds few Gay-Lussac degrees. Diln. with $CaCO_3$, Na_2CO_3 or $NaHCO_3$ caused more rapid deterioration, in order named. Diln. with sand or talc had no effect on keeping qualities. Stability is excellent when samples are kept in sandstone or metallic containers and much less loss of chlorine than with ordinary bleaching powder over period of several months.—*C. A.*

Hypochlorous Acid in the Sterilization of Water, Especially in the Prevention of Algal Growths in Cooling Water. A. GREGOIRE. Rev. Univ. Min. (Fr.) **15:** 584 ('39). Hypochlorous acid, produced on spot and added to water, has immediate bactericidal and algicidal action. Effect much more rapid than that of other chlorine compounds, such as Eau

de Javel, which are active bactericidal agents only when they have been converted to hypochlorous acid. Other advantages of use of hypochlorous acid are that free chlorine not formed, certain organisms resistant to chlorine, chloramine, and copper sulfate destroyed, odors removed, and cost low. Author describes Solvay process for disinfection of water by hypochlorous acid produced on spot and gives detailed, illustrated description of plant used for treatment of cooling water at power station at Brussels.—*W. P. R.*

Chlorinating New Mains. PHILIP J. HOLTON, JR. W. W. Eng. **93:** 172 (Feb. 14, '40). Since '36 all new mains in Providence, R. I., sterilized by means of hypochlorite soln. and portable feeder mounted on meter. Dose used, 50 p.p.m.; found necessary also to soak hemp in 100 p.p.m. hypochlorite soln. before placing in joint. Chlorinated water held in pipe at first for 48 hr., this later increased to 7 days. In '36–'38 inclusive, 178 extensions to mains made amounting to over 150,000′ of 6″, 8″, 12″ and 16″ pipe; present sterilizing method entirely satisfactory in eliminating coliform bacteria in one treatment.—*Martin E. Flentje.*

Methods and Practices in Sterilizing Newly Laid Mains. ANON. Pub. Wks. **70:** 11–24 (Nov. '39). Of 363 replies received to questionnaire sent to waterworks supts. throughout country, only 243 reported new mains were sterilized. Of possible methods of application, 3 principally used: (1) application of liquid chlorine through special chlorinator or directly from cylinder; (2) placing hypochlorite in line during laying; (3) injection of hypochlorite solution into mains during filling. In general chlorine application of 50 p.p.m. used with retention of chlorinated water in pipe for 24 hr. or more and in some cases subsequent checking of safety by bacterial analysis. Practice of various depts. given briefly.—*Martin E. Flentje.*

CORROSION AND CORROSION CONTROL

A Method of Measuring Corrosiveness. J. H. WALKER. Proc. A. S. T. M. **40:** 1342 ('40). Corrosion com. of National Dist. Heating Assn. devised corrosion tester consisting of 3 helical coils of bessemer steel wire mounted on frame which can be inserted in pipes of heating system. Tests made on steam condensate at 4 dist. heating plants operated by Detroit Edison Co. These showed no direct relation between D. O. and corrosivity but good correlation between product of CO_2 conc. and velocity of flow and corrosion rate in inches per year. Limitations as well as possibilities of method discussed. Pointed out that measurement of corrosiveness of environment does not necessarily indicate life of equipment.—*T. E. Larson.*

Measuring the Scale-Forming and Corrosive Tendencies of Water by Short-Time Tests. E. P. PARTRIDGE AND G. B. HATCH. Proc. A. S. T. M. **40:** 1929 ('40). Tests of stability and corrosivity of water recommended in supplement to chem. analysis for judging utility of water for industrial purposes. Short-time tests classified and discussed. Rate of supply of inhibitor, factor to be considered rather than concentration alone when inhibitor functions by adsorption on solid surface.—*T. E. Larson.*

Steam Sampling to Detect Corrosion. C. E. JOOS. Power Plant Eng. **45:** 69 (Mar. '41). Corrosion caused by dissociation of H_2O into hydrogen and oxygen can be indicated by separating gases from steam and analyzing for hydrogen. Resulting steam condensate free from CO_2 and NH_3 and satisfactory for conductivity detns. to determine steam quality. Equipment for continuously degasifying steam samples described.—*T. E. Larson.*

A Review of Data on the Relationship of Corrosivity of Water to its Chemical Analysis. V. V. KENDALL. Proc. A. S. T. M. **40:** 1317 ('40). Following brief review of available data on relationship,

author presents hot-water service data (17 cities) to show that after initial period, rate of corrosion (rate of pitting) more or less constant. Corrosive character best indicated in short time periods before retarding effect of rust coating becomes predominant. In using service test data for rate figures, very important to consider period of exposure. Specific elec. conductivity and corrosivity show some (questionable) correlation.—*T. E. Larson.*

Controlling Factors in Galvanic Corrosion. W. A. WESLEY. Proc. A. S. T. M. **40:** 690 ('40). Anode and cathode polarization curves given for iron and copper, respectively, in aerated 3% sodium chloride solution. Results can be expressed by empirical equation $V = I\ (R + K/A_c)$, where I is galvanic current, R is total unpolarized resistance of circuit, A_c, cathode area, K, constant and V, constant in most cases equal to open circuit e.m.f. of couple. Principle that galvanic corrosion current is directly proportional to cathode area deduced to be valid at moderate ratios of cathode area to anode area in solutions of good conductivity but shown to be inapplicable at high ratios where retarding effects of resistance and anode polarization become important. Practical aspects discussed.—*T. E. Larson.*

Standard Methods for Controlling the Thickness of Galvanized Zinc Coatings. D. S. ABRAMSON. Zavod. Lab. (U. S. S. R.) **9:** 390 ('40). Review of various standard methods for determining thickness of galvanic zinc coatings. Best method for detg. ave. thickness is by removal with Bauer soln. Ave. thickness does not give indication of corrosion resistance, so suggested that local thickness be considered. Drop method of detg. local thickness applicable for rough determinations in case where stream or volume method cannot be used. Method requires considerable time and errors are ±20%. Most accurate results, not dependent on structure and porosity of coating, obtained with stream method using soln. of NH_4NO_3, 70, $CuSO_4$, 7 grams per liter, and N HCl, 70 ml. per liter. Accuracy of method is ±10%. Volume method best adapted for plant tests; accuracy of results ±16%. 38 refs.—*C. A.*

Atmospheric Durability of Steels Containing Nickel and Copper. N. B. PILLING AND W. A. WESLEY. Proc. A. S. T. M. **40:** 643 ('40). Six series of atmospheric corrosion tests on sheet specimens of low copper and nickel alloy steels in rural, urban, industrial and marine atmospheres show that weathering resistance increased with increased nickel content and enhanced by addition of optimum amounts of copper. In marine atmosphere superiority of nickel-copper steels over copper steels particularly pronounced. Manganese, silicon and carbon contents do not appear to be important, but presence of moderate amts. of phosphorus seems to be beneficial in nickel-copper steels.—*T. E. Larson.*

Zinc Is Anti-Corrosive. A. H. STUART. Paint Mfg. (Br.) **9:** 2: 49 ('39). Tests carried out on corrosion-resisting properties of pure zinc on surface of iron, of zinc coating on layer of iron-zinc alloy, and of coating applied by "Duraspray" process, in which priming coat of red lead in oil first applied, and, while this is still tacky, zinc dust sprayed on with dried compressed air. Found that film of zinc, insulated by oil film or otherwise, capable of protecting iron surface from corrosion, and such coating does not possess brittle iron-zinc alloy film found in galvanized iron. When rupture does occur in zinc coating insulated by oil film, corrosion not so rapid as is the case when zinc is in electrical contact with iron.—*I. M.*

Corrosion of Metals in Connection With Microbiological Processes. E. A. REĬNFEL'D. Microbiol. (U. S. S. R.) **8:** 1:33 ('39); Khim. Referat. Zhur. (U. S. S. R.) **12:** 124 ('39). Corrosion of metals under influence of products of activity of bacteria (thiobacteria, denitrifying bacteria and bacteria causing hydrogen sulfide fermentation) which live in depths of petroleum deposits investigated. Sterilized plates of metals (chromium, nickel, chromium-molybdenum, copper, and

"EY a-18T" steels, "furodite" and "fekhtal") immersed in elective nutritive solns. with cultures of bacteria separated from deep-layer waters or subjected to action of waters with their natural microflora. Expts. lasted from 3.5 to 24 mo. Max. destruction of not only ordinary, but also of alloyed, steel caused by thiobacteria, which changed reaction of medium from pH 7.2 to pH 5. Min. effect obtained from denitrifying bacteria. Chromium steels most stable in all media. Losses of metals in water with natural microflora 13 times greater than in same water which has been preliminarily sterilized. Rate of corrosion increased with increase of duration of expts.—*C. A.*

Some Observations of the Potentials of Metals and Alloys in Sea Water. F. L. LaQue and G. L. Cox. Proc. A. S. T. M. **40:** 670 ('40). Preliminary results presented on particular method of determining potentials of no. of metals and alloys by use of specimens insulated from each other and placed in form of pipe through which well-aerated sea water circulated during test period of 6 mo. On basis of these data and those of other investigations by same authors, galvanic series in sea water presented (adjacent). Materials may change places within any group depending on incidental exposure conditions. Galvanic effects within groups not likely to be appreciable. Intensity of galvanic effect with other combinations will be determined by relative areas of materials forming couple and by distance apart. Recommended that materials of relatively low area and high in list not be connected with materials of large area lower in list. Reverse relationship not likely to be as troublesome.—*T. E. Larson.*

GALVANIC SERIES IN SEA WATER

Anodic

Magnesium
Magnesium alloys

Zinc
Galvanized steel or galvanized wrought iron

Aluminum 52SH
Aluminum 4S
Aluminum 3S
Aluminum 2S
Aluminum 53S-T
Alclad

Cadmium

Aluminum A17S-T
Aluminum 17S-T
Aluminum 24S-T

Mild Steel
Wrought iron
Cast iron

Ni-Resist

13% chromium stainless steel, type 410 (active)

50–50 lead tin solder

18–8 stainless steel, type 304 (active)
18–8–3 stainless steel, type 316 (active)

Lead
Tin

Muntz metal
Manganese bronze
Naval brass

Nickel (active)
Inconel (active)

Yellow brass
Admiralty brass
Aluminum bronze
Red brass
Copper
Silicon bronze
Ambrac
70–30 copper nickel
Comp. G-bronze
Comp. M-bronze

Nickel (passive)
Inconel (passive)

18–8 stainless steel, type 304 (passive)
18–8–3 stainless steel, type 316 (passive)

Cathodic

The Corrosion of Copper Pipes. Masazo Watanabe. Mitt. Med. Akad. Kioto. (Japan) **26:** 419 ('39). Distilled water continuously attacks copper. Upon immersion of bright sheet of copper (surface 100 sq.cm.) in 1 liter of distilled water, 0.05, 0.86, 1.32, 1.76 and 3.62 mg. per liter, determined by dithizone

method, dissolved at room temp. after 6, 24, 72, 120 and 240 hr., respectively. At concentrations studied, sodium hydroxide and potassium hydroxide usually more protective than distilled water; 10^{-3} N solns. had greater protective action than 10^{-2} or 10^{-4} N solns. Corrosive action of various solns. increased with increasing concentrations. Even at same concentration, however, action varied with kind of soln. and decreased in order: hydrochloric acid, sulfuric acid, nitric acid, oxalic acid, acetic acid, water, potassium hydroxide, sodium hydroxide at 10^{-2} and 10^{-3} N; acetic acid, hydrochloric acid, sulfuric acid, oxalic acid, nitric acid, water, potassium hydroxide, sodium hydroxide at 10^{-4} normal. During expt., pH of solns., determined with antimony electrode, shifted in acid direction. Solubility relations with respect to corrosion of lead by solutions of various concentrations appear to be much more complicated than those of copper corrosion. Both protective action and slight dissolving of copper or lead in alkaline solns. due chiefly to removal of corrosive carbon dioxide through carbonate formation. Metal attacked relatively strongly by very dilute alkaline solns.—*C. A.*

The Effect of Various Inorganic Salts on the Corrosion of Lead Pipes. TAMENAKA MATUBARA. Mitt. Med. Akad. Kioto. (Japan) **26:** 199 ('39). Action of 0.25, 2.5 and 10% solutions of various salts and effect of dissolved gases, especially oxygen and carbon dioxide, in distilled water, on immersed lead pipes, was studied with dithizone method of Fischer. Compared with ordinary distilled water, salt solutions studied had more or less protective action on lead. With increase in salt concentration, protective action of sodium chloride, potassium chloride, dipotassiumphosphate, sodium carbonate and potassium carbonate became weaker, while that of sodium nitrate, potassium nitrate, sodium sulfate and potassium sulfate increased. Corrosion of lead by salt solution did not always depend on pH alone. Boiled, almost air-free distilled water or distilled water saturated only with carbon dioxide dissolved little lead, but water saturated with oxygen much more corrosive. Water saturated with oxygen and containing large amount of carbon dioxide, however, only slightly corrosive, since resulting basic and neutral lead carbonates formed protective layer. —*C. A.*

The Corrosion of Steel Pipe in Clay, in Absence of Electric Currents. H. STÄGER AND W. BÉDERT. Schweiz. Arch. Angew. Wiss. Tech. (Switz.) **6:** 306 ('40). Authors give summary of previous investigations, mainly in U. S. and some European countries, dealing with corrosion due to partial change of surrounding air, conductivity and H-ion concentration of ground, salt content of ground, change of pipe from one type of ground to another, moisture of ground, bacteria in presence of sulfates and organic matter in absence of oxygen. Their own expts. deal with partial change of air and they found that initial corrosion caused brown spots formed mainly by ferric oxide while progressive corrosion, having less oxygen available, showed white stains containing ferrous oxide and ferrous carbonate. Frequently, currents flowing in pipes situated at foot of hills from up-hill part (oxygen deficiency) to off-hill part (oxygen excess).—*C. A.*

The Corrosion of Underground Piping. C. H. S. TUPHOLME. Mining Mag. (Br.) **63:** 177 ('40). Fundamental causes of each type of corrosion discussed, and methods of protection outlined. Cathodic protection not yet employed in England, but described, and some cost figures given. Prolonged tests have shown that properly applied cement mortar gives excellent protection and is preferable to ordinary cement because less porous. Expts. with cellulose nitrate plastic satisfactory. At first, celluloid shields used for repairs sealed with cold asphalt paint, but later, coating of grease found more satisfactory.—*C. A.*

Corrosion of Iron in Water. Influence of Low Concentrations of Sodium Silicate. D. J. E. VERONELLI. Industr. y Quim.

(Argentina) **2:** 183 ('39). Author discusses chemistry of corrosion of iron in water, formation of protective films, and effect of movement of liquid, pH value of liquid, oxygen, carbon dioxide, alkalinity, and temp. Expts. described on effect of addition of sodium silicate on corrosion under different conditions of pH, temperature, and content of oxygen and of salts. Corrosion of iron found to be reduced by addition of small amts. of sodium silicate. Reduction could not be ascribed solely to increase in pH value. After passage of water containing sodium silicate, iron continues to show resistance to corrosion when untreated water is passed over it; apparently there is formed a protective film of iron silicate. Rate of corrosion increases with increase in temp. but increase is slower in water containing sodium silicate than in untreated water. Higher the concentration of dissolved oxygen in water, more marked the effect of presence of sodium silicate. Effect of sodium silicate greater in distilled water than in water from Buenos Aires supply. —*W. P. R.*

A. C. Does Not Damage Water Pipes. ANON. P. P. Eng. **44:** 11:62 (Nov. '40). Except for title and introduction, almost word for word duplicate of summary of "Progress Report of the American Research Committee on Grounding" (Jour. A.W.W.A., **32:** 1946 ('40)) presented. One conclusion (not in A.W.W.A. summary) reads as follows: "some evidence which would indicate that deep well waters may, when soft and high in free CO_2, if not treated with lime, cause initial corrosion of copper tubing which would result in blue staining. These conditions may become more serious when hot water is heated to too high a temp." 21 cases of grounding investigated and reported, but in no case was there evidence of damage due to electrolysis by a.c. Lab. studies using a.c. on electrolytic cells (0.1 *N* NaCl) were reported to have indicated that zinc electrodes polarize less than copper electrodes, and that about 50 times as much a.c. as d.c. was required to cause comparable polarization. Report concluded with: "However investigations have not progressed sufficiently to prove that such damage (electrolysis by a.c.) could not occur."—*T. E. Larson.*

Non-Corrosive Paint for Steel Work. ANON. Eng. News-Rec. **126:** 558 ('41). Data given from lecture by Charles H. Ellaby at Chicago Museum of Science and Industry on research leading to development of paint for steel control gates on 33 dams of Upper Mississippi and Illinois Rivers. Average area of steel surface on each dam 250,000 sq.ft. Alternate wetting and drying severe on paint coatings and abrasion by driftwood also to be contended with. Paint originally employed, consisting of lead pigment in linseed oil vehicle, failed within 2–3 mo., permitting serious corrosion. 8 yr. of intensive investigations indicated that most economical, durable and satisfactory protection obtained by following procedure: (1) complete removal of all mill scale by acid pickling or sand-blasting; (2) inhibitive treatment of newly cleaned surfaces with phosphoric acid-sodium dichromate solution; and (3) application of at least 3 coats of synthetic phenol resinoid tung-oil varnish vehicle paint pigmented to suit particular condition existing. Coatings obtained excellent after 2 yr. service.—*R. E. Thompson.*

The Effect of Protective Coatings on the Corrosion-Fatigue Strength of Steel. T. J. DOLAN AND H. H. BENNINGER. Proc. A.S.T.M. **40:** 658 ('40). Lab. tests on steels protected with thin electroplated cadmium (.0001″) and zinc (.00015″) coatings, with cyanide (.004″), with silicon (.02″) impregnation and with nitride (.02″) showed following relative endurance limits. Endurance limit of untreated specimens in water .224 of endurance limit in air. Cadmium plating increased ratio to .254, zinc plating to .418 and cyaniding to .238. Nitrided case more efficient, underwater endurance limit being 80.9% of endurance limit in air. Specimens with silicon impregnation coatings of same endurance limits in air and in water. In all cases water continuously replenished at 63°F. and of 250–300 p.p.m. hardness, 6–8 p.p.m. D.O. and of pH 7.8–8.2.—*T. E. Larson.*

Red Water Stopped by Simple Treatment. ANON. Am. City. **56:** 6:70 (June '41). Chappaqua, N. Y., part of Water Dist. No. 1 obtaining water from Catskill Aqueduct of New York City System. Dist. system has 60 mi. of mains and 1,000 customers. Pumping plant houses chlorinators and lime feeders. Lime fed to maintain pH 8.3 to prevent corrosion and red water, but not successful. Sodium hexametaphosphate at 4 p.p.m. added. Later reduced to 1.5 p.p.m. and and lime feeding discontinued. Results, shown by complete prevention of pick-up of iron and elimination of discolored water due to iron oxides, excellent.—*F. J. Maier.*

Tests of Corrosion Inhibitors for Water Treatment in Air-Conditioning Equipment. J. H. WILSON AND E. C. GROESBECK. J. Res., Natl. Bur. Stand. **24:** 665 ('40). Corrosion by circulating water used in air-conditioning equipment much reduced by treatment of water with small amts. of corrosion-inhibiting chemicals, and by control of pH value. All inhibitors tested, except sodium carbonate in conc. of 100 p.p.m., decreased rusting of iron and steel in tests of 14 days duration. Substances tested, in order of decreasing efficiency, were chromates, silicates, phosphates, and carbonates. In tests with silicates, results indicated that the higher the ratio of silica to sodium oxide the greater the inhibiting action.—*W. P. R.*

Combating Internal Corrosion in Hot-Water Pipes. S. F. KOPJEV. Teplosilovoe Khoz. (U. S. S. R.) No. 1: 10 ('39); Chem. Zentr. (U. S. S. R.) No. II: 218, ('39). Cause of internal corrosion of steel hot-water pipes to be found in action of oxygen contained in water on iron of pipes. Presence of oxygen in water result of sucking in of air through leaks in pipes and replacement of water lost by water having high oxygen content. To prevent sucking in of air, pressure at all points of system should be greater than atmospheric pressure. Various devices for regulating pressure of hot-water systems explained. To remove air carried along mechanically rate of flow of circulating water must be reduced to 0.1–0.2 m./sec. —*C. A.*

Corrosion in Hot Water Systems and Its Prevention. H. KLAS. Stahl u. Eisen. (Ger.) **60:** 41 ('40). Author discusses causes and nature of corrosion in hot water systems, and methods of prevention. Corrosion in cold water distr. systems and boilers influenced primarily by external conditions such as composition of water and methods of operation. Differences in material of which pipes, etc., made and even such chemical and physical differences as those between steel and cast-iron, in comparison, of little effect, although may cause local corrosion by formation of electric elements. In hot water systems, however, greater importance generally attributed to comp. of pipes, boilers, etc.; opinions published concerning corrosion in these systems contradictory. Higher temps. of water reduce solubility of gas and increase that of salts, disturb carbonate equilibrium, and increase rate of all reactions. Most metals practicable for use are susceptible to corrosion. Copper resistant except to soft water containing much carbon dioxide or to water containing much chloride, but too expensive for general use. Pipes with thin lining of copper developed. Aluminum not satisfactory; glass resistant to corrosion but mechanically unsatisfactory; porcelain has been used for storage of water. Steel still most economical material; rustless steel alloys, however, not available in sufficient quantities and too expensive. Corrosion of metal by hot water, often leading to rusting followed by perforation, described. Bottoms of tanks and heating coils generally most seriously affected; distribution pipes suffer less. Compounds found in cavities formed by corrosion vary with nature of water; oxides of iron always present. Content of calcium carbonate varies, chlorides and sulfates present only in small quantities, and ionized iron usually absent. Presence of dissolved oxygen in water, and existence of cathodic and anodic areas in system are most important causes of corrosion. Variations in chemical or physical condition of surface, deposition of sediment, and liberation of gas against heated surfaces of system may all induce formation of cathodic and anodic areas. Effect may be prevented by neutralizing ca-

thodic and anodic areas, by removing oxygen from water, or by protection of metal. Further progress of corrosion, leading to perforation, may be influenced by other factors, particularly comp. of water, temp., which affects rate of deposition of protective layers and solubility of oxygen, and pressure. The content of oxygen appears to be unimportant compared with the rate of diffusion of oxygen in water in neighborhood of cathode; rate increased by 3% for every 1° rise in temp. Dissolved oxygen, not gaseous oxygen, of importance; with increased pressure capac. of water to hold dissolved oxygen when temp. raised greater than when pressure low so that content of oxygen in water for high pressure plants may be higher than in water for low pressure plants at same temp. Removal of oxygen from soln., by means of sodium sulfite, iron turnings, or manganese steel wool, described. Protective coating of metal may occur naturally through formation of oxidized layers or deposition of calcium carbonate, latter being most effective in preventing initiation of corrosion. Methods of preventing progress of corrosion include removal of acid by filtration through "Magnomass," addition of phosphate with resulting formation of protective layers, and protection of storage tanks through simultaneous induced polarization and deposition of protective layers. Commercial application of these methods discussed. For small concerns, small houses, etc., use of low pressure heaters, filtration of water through iron turnings, or protection by addition of phosphate recommended. For larger houses and factories, where supervision can be provided, addition, in regulated amts. of phosphate or of materials to combine with oxygen, treatment with magnomass, or electrical protection of metal recommended. Advantages and disadvantages of galvanized steel, steel plated with copper, rubber, or resins, enamel linings or linings of inorganic substances, such as cement, discussed. Coatings of organic materials such as oil varnish or bitumen in general not resistant to heat; artificial resins provide good protection for limited time. Storage tanks can be protected in same way as pipes; such protection not practicable for heating coils, and these should either be of copper or construction of system should be such that they are easily replaceable.—*W. P. R.*

Constancy of Application Is Important Factor in Cathodic Protection. NEIL WILLIAMS. Oil Gas J. **39:** 30:53 ('40). Experience has shown that all corrosion of iron ceases when negative potential built up is below −0.2853 v. For pipe lines to which electrical energy supplied by wind chargers, dual installation consisting of direct connection to line of 32-v. charger and 12-v. unit maintaining 225-amp.hr. storage battery for use when wind failed proved very effective. Transfer from direct to battery supply automatic.—*C. A.*

Relationship of Current Density to Cathodic Protection. WALTER F. ROGERS. Petroleum Engr. **12:** 1:156 ('40). Lab. and field tests indicate current density better criterion of protection on bare or poorly coated pipe than pipe-to-pipe potential. Field tests, over period of 147 days in corrosive soil, indicate current density of 3.65 to 8.2 ma. per sq.ft. gave 76.2% to 100% protection, even though pipe potentials below so-called min. protection potential for at least 60 days during test period. Lab. expts. on corrosive artificial soil showed that 45.8% to 100% protection afforded with densities ranging from 2 to 16 ma., even though only 2 of final potentials above 0.8, and complete hydrogen polarization occurred in only one case. Test data tabulated and exptl. apparatus shown diagrammatically.—*C. A.*

Electrical Bonding for Cathodic Protection of Pipe Lines. SCOTT EWING. Gas **17:**1 : 21 ('41). New pipe lines on which cathodic protection may be used in future should have conducting couplings or be bonded. New type of bond suitable for either old or new lines described. Consists of a 3/16″ copper strip of suitable width, factory-bonded into steel ferrules, curved to fit 6″ pipe, and also provides steel wire to connect with pipe coupling. Ferrules more read-

ily welded in field to steel pipe than is copper, and good welds essential to avoid corrosion between bond and pipe. After welding, coat of primer applied to wire, terminal, weld and adjacent pipe and then coating of hot enamel, followed by additional coat of enamel after pipe has cooled sufficiently.—*C. A.*

Pipe-to-Soil Potentials in Cathodic Protection (Pipe-Line) Systems. WALTER F. ROGERS. Petroleum Engr. **11:** 13:33 ('40). Measurements made of potential differences between copper-copper sulfate electrode and steel pipes in various types of soil at different times of yr. Uncoated lines showed widely variant voltages, averaging 0.54 v. for tight, wet soils and 0.20-0.26 v. for dry, well-aerated soils. Adequately coated pipes show value close to 0.54 v. in any type soil. Value apparently the value for normal steel pipe even though not criterion of corrosion, since pipe sometimes corrodes at higher voltages, and often does not corrode with voltages as low as 0.17. On ave., voltages in fairly wet weather 0.12 v. higher than in relatively dry weather. No clear evidence of voltage "build-up" apart from change due to moisture content. According to theoretical calculations, given for expected voltages with Fe^{+++}, Fe^{++} and oxygen electrode, value of 0.54 v. presumably due to $Fe^{+++}-O$ or perhaps to $Fe^{++}-O$ electrode. Seasonal variations and current-time influences on pipe potential discussed.—*C. A.*

HYDRAULICS

Viscous and Turbulent Flow. Its Application to Metering. A. LINFORD. Civ. Eng. (Br.) **35:** 279, 341 (Oct., Dec. '40). Where small flows are being dealt with or where fluid has high coef. of viscosity, unless due precautions are taken, may be found that, over part of flow range, fluid may be moving through meter in partly streamlined condition, under which circumstance considerable errors in flow registration may result. To obtain clear conception of basic principles underlying flow of all fluids, theoretical considerations based on absolute units. Mass designated by M, length by L, time by T, and force by F. Shown that rate of flow through any differential-pressure-producing device [such as Venturi meter] is function of linear dimension of meter, differential pressure, and density of fluid being metered. Fourth factor which must be considered is viscosity of fluid. Shown that in a manner similar to compressibility, friction has no appreciable influence on discharge coefs. of flow meters. Equation for velocity in streamlined flow indicates parabolic velocity distribution, mean velocity of flow being half velocity along axis. Under turbulent flow conditions, flatter velocity distribution curve obtained, mean velocity approx. 0.8 times center velocity. Under streamlined flow conditions:

$$Q = \frac{\pi R^4 (p_1 - p_2)}{8\mu l}$$

and for turbulent flow conditions:

$$Q = Cd \frac{A_1}{\sqrt{r^2 - 1}} \sqrt{\frac{2g(p_1 - p_2)}{e}}$$

where Q is volume of flow in unit of time; C is constant depending on ratio of physical dimensions of flow conduit; Cd is coef. of discharge, A_1 and A_2 are cross-sectional area of conduit at upstream section and at downstream section, respectively; r is ratio of A_1 to A_2; p_1 and p_2 are pressures at these respective sections; e is M/L^3; and μ is viscosity. Since there is no change in kinetic energy when fluid is in streamlined motion, complete viscous flow can be obtained in parallel pipe through which is flowing an incompressible fluid; but viscous effect always present in fluid in motion and point of practical importance is magnitude of this effect in relation to inertia forces. This can be ascertained only by studying experimental data. If frictional force per unit area resisting

motion equals F, then practical investigation shows that for smooth pipes:

$$\frac{F}{eV^2} = \left\{0.0009 - \frac{0.0763}{\left(\frac{VDe}{\mu}\right)^{0.35}}\right\}$$

in which D is linear dimension. Apparent that e of fluid increases resistance to turbulent flow, importance of effect diminishing as coef. of roughness and velocity, and, hence, inertia forces increase. Similar conditions for streamlined flow can be expressed as:

$$\frac{F}{eV^2} = \frac{8}{\frac{VDe}{\mu}}$$

Two equations present complete picture of two conditions of fluid flow. Should be noted that there is no sudden changeover between streamlined and turbulent flow. Fundamental term in fluid flow is: $\frac{VDe}{\mu}$, which is called Reynolds no. Significance of Reynolds no. will be appreciated from dimensional analysis of flow meter formula. Equation can be developed to obtain common basis for model testing, in which Q equals $C_1 D^2 \sqrt{\frac{p}{e}}$ and

$$\sqrt{f_1\left(\frac{VDe}{\mu}\right)^d} = C_1 D^2 \sqrt{\frac{p}{e}} f_2\left(\frac{VDe}{\mu}\right)$$

in which C_1 is coef., and f_1 and f_2 represent function. Clearly demonstrates that coef. of discharge is function of Reynolds no. Thus, discharge coefficient of flow meter may be obtained by testing model over same values of Reynolds no., due precaution, of course, being taken to ensure geometrical similarity in all respects between model and prototype. Letting suffix m refer to model and suffix a refer to prototype, dynamic similarity is obtained when

$$\frac{V_m D_m e_m}{\mu_m} = \frac{V_a D_a e_a}{\mu_a}$$

If both model and prototype are of same degree of smoothness, friction effect is cancelled. Effect of change in density with change in pressure, when dealing with compressible fluids, makes considerable modification to treatment necessary in obtaining flow formula. By introducing coef. of discharge, C_d, and expressing differential pressure in terms of gravitational units, $p_1 - p_2$ lb. per sq.ft., compressible fluid flow formula becomes

$$Q = (Cd\theta)\frac{A_1}{\sqrt{r^2 - 1}}\sqrt{2g\left(\frac{p_1 - p_2}{e_1}\right)}$$

in which θ = compressibility factor. Principles of dimensional similarity are universal and apply both to irregular shape conduits and conventional design of Venturi tube, orifice, nozzle, etc. Method of using irregular shaped conduit as flow meter is illustrated. Rather interesting point occurred with model. Viscosity of gases increases with temp., and this phenomenon enabled model to be calibrated with air at atmospheric pressure and temp. over same range of Reynolds no. as prototype, without introducing compressibility effects.—*H. E. Babbitt.*

Turbulence in Open Channel Flow. A. A. KALINSKE AND J. M. ROBERTSON. Eng. News-Rec. **126:** 539 (Apr. 10, '41). Diffusive action of turbulence, which makes possible transportation in suspension of heavy particles, investigated by injecting through fine tube at point in open rectangular water channel a mixture of carbon tetrachloride and benzine containing powdered anthracene, motion pictures being taken of spread of particles. Results shown graphically and discussed. Conclusions: (1) Turbulence in streams can be quantitatively investigated by diffusion experiments. Turbulence diffusion coef. and intensity of turbulence can be measured from such expts. (2) Momentum diffusion coef. as calculated from shear and velocity distr. curve indicative of ability of turbulence to transfer sediment in streams and keep it in suspension. (3) Turbulence near surface of stream such that much greater ability to diffuse material laterally than vertically.—*R. E. Thompson.*

Flow of Muds, Sludges and Suspensions in Circular Pipe. D. H. CALDWELL AND H. E. BABBITT. Ind. Eng. Chem. **33:** 249 (Feb. '41). Among other industries, water and sewage treatment and dredging can profit from knowledge of flow characteristics of muds, sludges and suspensions. Flow of sludges is classed as "plastic" and "turbulent," point of change being "critical velocity." Authors present previously known equations for plastic flow and new equations for critical velocity and turbulent flow, all verified by tests by authors or by tests reported in the literature. For plastic flow:

$$\frac{H}{L} = 32\left[\frac{Ty}{6\rho D} + \frac{\eta V}{g\rho D^2}\right]$$

and

$$V = \frac{gD}{8\eta}\left(Tp - \frac{4}{3}Ty\right)$$

Between upper and lower critical velocities lies region of uncertainty as to whether plastic or turbulent flow will exist. Apparently, exact value of critical velocity is controlled by roughness of pipe.

$$V_{lc} = \frac{1000\eta + 1000\sqrt{\eta^2 + \frac{D^2 Ty\rho g}{3000}}}{D\rho}$$

and

$$V_{uc} = \frac{1500\eta + 1500\sqrt{\eta^2 + \frac{D^2 Ty\rho g}{4500}}}{D\rho}$$

If roughness of pipe is accurately known, exact value of critical velocity can be calculated by:

$$V_c = \frac{8\eta + 8\sqrt{\eta^2 + \frac{fTy\rho D^2 g}{24}}}{f\rho D}$$

Tests made at Univ. of Ill. show that familiar friction factor, Reynolds no. chart, may be used, with certain limitations, for calculating flow of sludge in turbulent region. If viscosity of dispersion medium is used in determining Reynolds no., corresponding friction factor is same as if true fluid such as water were flowing material. Therefore, yield value and rigidity of sludge have no effect on friction loss in *turbulent* flow. At high Reynolds nos., friction factor chart lines become nearly horizontal, indicating that, there, friction losses vary as square of velocities. Chart shown gives latest available data for flow in various kinds of pipes and can be used for solving sludge flow problems with restrictions stated. Definitions of symbols: H = difference in static head between 2 points in a pipe in ft. of flowing substance; L = length of pipe in ft.; Ty = yield value or shearing stress at yield point of plastic material in lb./sq.ft.; η = coef. of rigidity in lb./sec.ft.; V = mean velocity of flow in pipe in ft./sec.; ρ = density of flowing substance in lb./cu.ft.; D = diam. of pipe in ft.; g = acceleration due to gravity in ft./sec./sec.; Tp = shearing stress in flowing material at boundary or pipe wall in lb./sq.ft.; V_{lc} = lower critical velocity; V_{uc} = upper critical velocity; f = friction factor in Fanning's formula, which must be solved by trial and error: $H = 2fLV^2/gD$.—*Selma Gottlieb.*

Measuring Flow in Open Channels. H. G. WILM. Eng. News-Rec. **125:** 754 (Dec. 5, '40). Standard current meters and pitot tubes often unsatisfactory for measuring small flows containing some bed-load, silt and trash. Rod developed for making such measurements consists of strong 1″ x 3″ wood staff of convenient length, beveled and sheathed with thin copper on one edge, shod with brass plate, and graduated in feet and tenths. Depth is measured in 4 or more locations across stream by immersing rod with sharp edge facing upstream. Rod is then reversed so that 1″ face is turned directly upstream, which produces small hydraulic jump. Ave. height of jump above stream bed measures specific energy of flow at point of measurement, and net height of jump above normal water level measures actual velocity-head. Velocity computed by standard formula: $V = \sqrt{2gh}$, in which V =

velocity in ft. per sec., g = acceleration due to gravity, and h = velocity head. Ave. error, based on 37 measurements checked against calibrated weirs and flumes, is about ±1.64%. Limitations include inaccuracy for velocities much below 1′ per sec. and in streams with soft, unstable beds, and difficulty of handling in large, deep streams, or with velocities greater than 8′ or 10′ per sec.—*R. E. Thompson.*

Contribution to a Study of the Allen Salt-Velocity Method of Water Measurement. MARTIN A. MASON. J. Boston Soc. Civ. Engrs. **27**: 3: 207 (July '40). Numerous advantages inherent in Allen method, which make it more desirable than others for use in certain difficult cases, justify further study of method. Principal object should be to define field of application and possibility of its use in all types of conduits or channels. Approach to problem was first to develop physical conception of method and theoretical and experimental means employed to clarify this conception; and, second, to prove conception by expt. Most common errors concerning principle of method arise either from considering salt "cloud" as material screen, without taking account of continual agitation of particles and resulting mixing; or from considering only influence of local mean velocities and not turbulence velocities in formation and deformation of cloud. Before proceeding to study of behavior of "cloud" in water, flow process in conduit must be considered. First recall characteristics of 2 modes or regimes of flow in conduit or channel—laminar or viscous regime, and turbulent regime. From description of turbulent flow regime it appears that displacement of single particle along conduit is resultant of succession of translatory movements and small elementary rotations, causing continual mixing and interchange of particles. Thus, foreseen that, in rough conduit, characterized by elongated velocity distribution curve, "cloud" introduced into channel will be preserved as homogeneous mass. As cloud progresses along conduit, it increases in length as result of mixing process. Ave. axial distance traveled by salt particle along conduit is:

$$L_n = \frac{1}{n}\int_0^n L$$

in which L is axial distance traveled by a salt particle p_1. To be able to follow evolution of definite particles, suffices to modify or change in some way some property of transporting liquid or to add to it some property not previously existent. If one can perceive, and measure with precision, variation of property with respect to time, one has means of measuring mean cloud velocity, and, therefore, discharge of conduit or channel. In Allen method passage of a salt cloud past electrodes is detected and registered by means of galvanometer placed in electrode circuit. Necessary to know relation which must exist between concentration and conductance of salt-water mixture in order that location of mean point of cloud may be determined from registered current curves. Under these conditions, if potential difference, E, is applied to 2 electrodes separated distance, l, total instantaneous current resulting is

$$I = \frac{EA}{\rho l}$$

where ρ is specific resistivity of solution and A is area of electrode plates. Replacing resistance by conductance $\frac{1}{\rho} = kn$ (n being no. of salt particles per unit volume of salt-water mixture and k, some constant) it is noted that total instantaneous current is proportional to affected area of electrodes and cloud concentration. Method suggested by Allen assumes time required for cloud to traverse measuring section will be measured by distance between centers of gravity of two registered current curves. In reality such is not case. Registered curves will be deformed in sense that they do not represent instantaneous image of cloud but, rather, composite image of portions of varying figures assumed by cloud during its passage.

Experimental verification was sought. Tests were performed in 2 adjoining channels; one of rectangular profile (43 cm. deep, 52.5 cm. wide), and other parabolic (40 cm. deep, 89 cm. wide), each 18 m. long. Coloration tests confirmed thesis that cloud form changed constantly. In light of observations may be said that small quantities of salt solution are carried in every direction by transverse components of velocity and then dissociated and absorbed by small eddies until ensemble is assimilated by definite volume of water. Mechanism of turbulence was observed by ultra-violet light method and was found that throughout extent of channel, eddies turned in all senses and their axes were oriented in every direction. Has been stated that if degree of turbulence is high, and if distance of initial pair of electrodes from injection point is sufficient, mode of injection is not important. Practically, measuring section should be rather short as excessive attenuation of salt cloud and current curve which may result in large errors is avoided thereby. In most field applications, where flow velocities are usually high, probable that natural turbulence is sufficient for use of Allen method. Concluded that: (1) measuring section between electrode pairs and point of injection should be uniform in section and state of turbulence should be essentially same throughout entire channel or pipe; (2) measuring sections subject to disturbing influence of large scale eddies should be avoided; (3) requisite length of measuring section appears to depend primarily on state of turbulence in channel; (4) electrodes should cover essentially cross-section of channel; (5) worthwhile to note encouraging results obtained from use of calculus of probabilities when stream turbulence is high; and (6) method may not be used satisfactorily without sound knowledge of essential principles of its application, any more than other measurement methods.—*H. E. Babbitt.*

Calculation of Terminal Speeds. ANON. Engineering. (Br.) **150:** 441 (Dec. 6, '40). Laws of fluid motion govern max. or terminal speed attained by body falling freely through unrestricted volume of viscous fluid. In many problems, such as those involved in gravity sedimentation, particles are sufficiently near to spherical shape for usefully approx. results to be obtained by regarding them as spheres. In consistent units, let r = resistance to motion of sphere; d = diam. of sphere; v = speed of sphere relative to fluid; ρ = density of fluid; and η = viscosity of fluid. From considerations of dynamical similarity, may be shown that

$$r = \frac{1}{2}\rho V^2 \frac{\pi}{4} d^2 \phi\left(\frac{Vd\rho}{\eta}\right)$$

where ϕ is empirical function of group of factors, v, d, $\frac{\rho}{\eta}$, which is familiar Reynolds number, denoted by R. Law of resistance of spheres may thus be expressed as relation between two non-dimensional groups, one of which $\frac{8r}{\pi\rho v^2 d^2}$ may be termed a coefficient of resistance and denoted by ψ; while other is R. If $\log \psi$ is plotted against $\log R$, over range of Reynolds number less than about 0.3, curve is straight line of slope -1. Hence r varies as $vd\eta$, showing resistance to be proportional to first power of v. Analysis of problem under these conditions, due to Stokes, shows that $r = 3\pi vd\eta$. Consequently, throughout Stokes region, R and ψ may be combined to $\psi_s = \frac{24}{R}$. In second region, which extends from R = 1,000 to R = 250,000, ψ = approx. 0.44. Resistance is thus proportional to v^2 and inertia of fluid is its dominant physical property. Range is sometimes known as Newton region. Most practical problems involving terminal velocities occur at Reynolds numbers less than 250,000. In simple case of sphere of density, σ, falling under action of gravity, g, through fluid of density, ρ, accelerating force equals fluid resistance to motion and

$$\pi d^3 g\left(\frac{\sigma - \rho}{6}\right) = \rho V^2 \pi d^2 \frac{\psi}{8}$$

i.e. when

$$v^2 = dg\left(\frac{\sigma - \rho}{3}\right)\rho\psi$$

From which it can be shown that

$$v_s = d^2 ng\left(\frac{\sigma - \rho}{18\eta}\right)$$

in which v_s is velocity in Stokes region; and

$$d_s^2 = 18\,\frac{V\eta}{ng}\,(\sigma - \rho)$$

in which n is a factor by which g may be multiplied, as in a centrifuge. Throughout Newton region ψ may be taken as equal to 0.44, giving a max. error of about 7% for velocities and about 14% for diameters, either of which can often be tolerated. If v is expressed in ft. per sec., d in microns, and g = 32.2′ per sec. per sec., then

$$v = 0.0179\sqrt{\frac{dn(\sigma - \rho)}{\rho}}$$

and

$$d = \frac{3125\rho v^2}{n(\sigma - \rho)}$$

(Charts and illustrative solution given in article.) Generally, best method of treating cases of particles of irregular shape is to measure terminal speeds experimentally for typical samples, and deduce diam. of equivalent sphere. Important range of practical problems deals with bubbles, globules, or spheres of fluid moving through another liquid or gas. In such case "slipping" occurs. Lamb shows that if coefficient of sliding friction is zero, Stokes resistance of moving fluid sphere is $\frac{2}{3}$ that of equal rigid sphere. In Newton region ψ is independent of viscosity and, hence, sliding friction can be assumed to be negligible without affecting head resistance. Final point of interest concerns interference effects of particles moving in relatively close proximity through volume of fluid. If concentration is greater than about 0.001 by volume, mass convection currents set up by differences of concentration, can attain velocities which are appreciable fraction of free falling speed of particles. Effect has been observed in concentrations approaching 0.0001 by volume with particles 50μ in diam. but is inappreciable for 200 μ particles in concentrations up to 1/300. Concentrations of order of 1% by volume have been observed to double falling speed in some cases.—*H. E. Babbitt.*

Loss-of-Head Determination in Uniformly Tapped Pipes. R. D. GLADDING. Eng. News-Rec. **125:** 697 (Nov. 21, '40). Determination of loss of head in pipe lines having outlets along length, *e.g.*, lateral sprinkler lines used in portable overhead irrigation systems, cooling systems in power plants, and sprinkler systems for sewage disposal, is problem of frequent occurrence. If assumed that outlets are evenly spaced and each outlet discharges same quantity, simple relationship to loss of head in pipe discharging total quantity at end may be found. Following formula is developed: $h = FKLQ^m$, *i.e.*, loss of head which would occur if all water passed entirely through pipe multiplied by factor F, which depends only upon no. of outlets. Figure is included from which values of F for various nos. of outlets may be read.—*R. E. Thompson.*

Gasoline Pipe Lines—Design and Construction. A. H. RINEY. Civ. Eng. **10:** 501 (Aug. '40). Gasoline pipe lines would be better termed "finished-product" pipe lines because many of them carry not only motor fuel but natural gasoline, butane, burning oils, kerosene, and distillate. Various materials are pumped in "slugs," one behind another, and are delivered free of contamination because lines are operated at rates which assure turbulent flow. First long-distance gasoline pipe line built in Calif. in '26—a 4′ line about 100 mi. long. Since that time growth rapid. In general, construction of gas, oil, and gasoline lines similar. Design of each type of

line, however, involves different hydraulic formulas. Gas flow equation has to take into account compressibility of gases. Formulas for flow of oil and gasoline do not have to consider compressibility, but they do have to take fluid friction into account. Williams-Hazen formula for flow of gasoline assumes that viscosity of all gasoline about same as that of water. Because of fractional exponents and no. of variables in all of these formulas, use of nomographs or alinement charts for solution of formulas is great time saver. Accuracy of solution by this method exceeds accuracy of data used.—*H. E. Babbitt.*

Example of Hardy Cross Method in Water Distribution Problem. W. M. SCOTT. Eng. Cont. Rec. **54:** 19:11 (May 7, '41). Hardy Cross method of determining distr. of flow and corresponding loss of head in system of pipes discussed and application illustrated in solving specific problem. Nomograph developed by H. Shand of Greater Winnipeg Water Dist. for determining values of 1.85 $kQ^{0.85}$ and $kQ^{1.85}$ included. Method may be employed for determining proper elev. for water stored on system and correct operating head for second pumping station delivering into mains.—*R. E. Thompson.*

Friction of Fluids in Solder-Type Fittings. PAUL F. BRUINS, DONALD F. OTHMER, KENNETH A. JAMES AND MARTIN BERMAN. Trans. Am. Inst. Chem. Engrs. **36:** 721 ('40). Pressure loss due to friction in streamlined copper fittings and in streamlined copper pipe is less than pressure loss in iron pipe and fittings of same actual internal diam. Due to differences in actual diam. of same nominal sizes for copper and iron pipe, however, pressure losses due to friction must be calculated for each individual piping arrangement to determine which has lower pressure loss. In making comparisons, allowance should also be made for effect of corrosion on pressure drop and length of life in case of iron pipe. Pressure loss due to friction in fittings not independent of velocity of flow.—*C. A.*

Investigations of the Discharge and Coefficients of Small Circular Orifices. F. W. MEDAUGH AND G. D. JOHNSON. Civ. Eng. **10:** 422 (July '40). Not always found practical by hydraulic experimenter to reproduce with sufficient accuracy such measuring devices as Venturi meter or weir. Most promising device is circular orifice in vertical side of large tank. Could be used to advantage if method of mfr. were developed which would consistently give a perfectly square inner edge to opening and if discharge coefs. for such an opening were known with sufficient accuracy for different heads and hole diams. Curves for orifices smaller than 2″ in diam. were obtained from following empirical formula which fits all data exceedingly well except for 2″ orifice

$$C = 0.5880 + \frac{0.0045}{d^{2/3}} + \frac{0.0075 + 0.0582(10^{-0.890d})}{\sqrt{H}}$$

where H is expressed in ft. and d in in. Writers have concluded that: (1) Coef. of discharge for perfect contraction is 0.588. (2) It should be possible for other experimenters to obtain coefs. within 0.33% of those given, for heads between 2.0 and 50.0′. Preferably orifices equal to or greater than 1″ in diam. should be used. (3) For heads in excess of 4′, values of discharge coefs. for 4″ orifices are about 0.1% less than those for 2″ orifice. Discharge coefs. of Smith and Walker, which are probably those in most common use at present time, are considerably greater than those obtained by writers.—*H. E. Babbitt.*

Miscellaneous Troubles in Heating and Hot Water Supply Systems. H. H. BRUCE. Baths & Bath Eng. (Br.) **7:** 73 ('40). Trouble due to retardation of circulation in heating and hot-water supply systems by presence of air in pipes of common occurrence, especially when systems run continuously. Liberation of dissolved oxygen and nitrogen when water is heated described. Expelled gas appears generally to be in

form of small bubbles, carried along with water stream. If several of these bubbles unite, larger bubble formed will have considerable buoyancy and may resist downward flow of water, considerably reducing amt. of head available. When flow of water is up pipe, bubble may travel faster than water. Recommendations given for evacuating air include grading of pipe, position of vents, and prevention of entry of air with water from feed pipe. Recommendations also made for operation of combined heating and hot-water systems, concerning control of air draft and temp., and efficiency of transmission of heat. In calculating heating surface required in calorifiers, effect of velocity of water flowing through tubes on transmission of heat must be considered. Serious reduction in transmission occurs as velocity of water reduced. Resistance to transmission provided by scale on water-to-water calorifiers often exaggerated, and effect dependent on other resistances involved.—*W. P. R.*

BOILERS AND FEED WATER

Silica in Boiler Feed Water and Methods for Its Removal. JOSEPH D. YODER. Southern Power and Ind. **59**: 2: 103 ('41). Not feasible to remove enough SiO_2 from boiler feed water to prevent caustic embrittlement. High SiO_2 content in boiler water may cause formation of turbine deposits, high in SiO_2 in certain stages; these deposits can only be removed with difficulty and when turbine is shut down. Low SiO_2 content is desirable for this reason. $CaSiO_3$ scales can form in boiler tubes; these are best prevented by reducing Ca and Mg to min. by external base-exchange or hot lime-soda softeners and by maintaining soluble phosphate in boiler water, together with alky. greater than 1 NaOH to 1 SiO_2. With high-capacity boilers, or when some parts of boiler evap. water at higher rate than other parts, part or all of salts may be deposited. Most of Na salts will redissolve, but if Na_2SiO_3 is dried, it becomes insol. This especially true when Al present, and NaAl silicate (analcite) scale is formed; this is most serious scale encountered, and is more pronounced as SiO_2 in water increases. Formation of this scale can be materially reduced by commercial installations which reduce SiO_2 to 2 or 3 p.p.m.—*C. A.*

Removal of Silica From Boiler Feed Water. RAY MCBRIAN *et al.* Am. Ry. Eng. Assn., Bul. 414 ('40) p. 101b. Silica in boiler feed water frequently causes hard, dense scale deposits. Max. limit of 5 p.p.m. will materially reduce such trouble. Internal treatment with phosphates, iron compounds, aluminates and organic compounds have proved effective in some cases. External treatment in lime-soda softening plants with recirculation of sludge and application of $Fe_2(SO_4)_3$ or Mg. or Al compounds at controlled pH has resulted in satisfactory removal of silica. Softener installed by Atlantic Coast Line R. R. at Savannah, Ga., reduces silica from 65 p.p.m. to 10 p.p.m. by treatment with lime and Na aluminate at pH 8.5.—*R. C. Bardwell.*

Removal of Silica From Water by Cold Process. L. D. BETZ, C. A NOLL AND J. J. MAGUIRE. Ind. Eng. Chem. **32**: 1320 (Oct. '40). Silica should be removed from water before it enters boiler. Freshly precipitated aluminum hydroxide (prepared from filter alum and sodium carbonate or sodium hydroxide and washed but not dried) was found most effective at 23°C. and relatively inefficient at 95°C. Retention time of 30 to 60 min. (with stirring) sufficient. 200 p.p.m. of $Al(OH)_3$ (dry basis) with 40 p.p.m. of NaOH decreased soluble silica from 20.0 p.p.m. to 1.0 p.p.m. at 23°C. with 1 hr. retention and stirring. When used with cold-process lime-soda softening, $Al(OH)_3$ removes silica as above, improves coagulation, increases efficiency of softening and somewhat lowers alkalinity of effluent. Lowest residual silica between pH 8.3 and 9.1, but residual Al in effluent increases sharply above pH 8.3, and desirable

treatment range is pH 7.6 to 8.0. $Al(OH)_3$ treatment does not increase total dissolved solids of effluent. Efficiency of $Al(OH)_3$ slurry decreases with age, and dry powder or commercial slurry has low efficiency. Removal of silica by $Al(OH)_3$ probably due to adsorption.—*Selma Gottlieb.*

Removal of Silica From Water by Hot Process. L. D. BETZ, C. A. NOLL AND J. J. MAGUIRE. Ind. Chem. Eng. **32:** 1323 (Oct. '40). Magnesium oxide, especially commercial product called Remosil, produced by Calif. Chem. Co., effective in removing silica from water by hot process. At 95°C., 15 min. detention with stirring sufficient. Optimum pH 10.1 and optimum hardness and alkalinity approx. those of good effluent from lime-soda softener. MgO can be added in course of hot-process lime-soda softening. Addition of 100 p.p.m. of MgO decreased soluble silica from 19 to 1 p.p.m. and also decreased hardness and alkalinity. Requirements of lime and soda ash are not affected. MgO less efficient at lower temp. (e.g., 23°C.) since some MgO then dissolves. Increase in MgO lowers silica residual. Results with MgO were better than with $MgSO_4$ or $Fe_2(SO_4)_3$. With last two named, solids content of water considerably increased but with MgO it is decreased. Remosil best of MgO products studied. Somewhat soluble and gives better floc formation and lower residual silica. Plant scale tests have given better results than lab. tests, silica being reduced as low as 0.1 p.p.m. and with less MgO than needed in lab., probably due to larger quantity of sludge being recirculated. Mechanism of silica removal by MgO not clear; formation of complex MgO-magnesium silicate complex or adsorption is suggestion.—*Selma Gottlieb.*

The Scaling of Boilers. Identification of Phases in Calcium Silicate Scales. L. M. CLARK AND C. W. BUNN. J. Soc. Chem. Ind. (Br.) **59:** 155 ('40). Describes results of exam. of state of combination of silica and calcium in boiler scales. Six boiler scales containing silica analysed; results of analyses and comp. of different waters from which scales deposited shown in table. Silica content in all scales high (30-46%); ratio of calcium oxide to silica appeared in all cases to be less than 2:1. Optical properties and x-ray spectra of calcium-silicate compounds in scales compared with those of no. of minerals containing silica. Optical evidence indicated, and study of x-ray spectra confirmed, that hydrated calcium silicate mineral xonotlite ($5CaO, 5SiO_2, H_2O$) was constituent of 4 of 6 examples of scale. In fifth scale, major silica-containing constituent contained also alkali metal, and was identified as pectolite ($Na_2O, 4CaO, 6SiO_2, H_2O$). Minerals xonotlite and pectolite synthesized, and spectra of scale, natural mineral, and synthetic mineral compared in each case. General similarity obtained confirms existence of fundamental crystal lattice for each group; differences of order known to occur in other series of mixed crystals. Methods of synthesis of minerals described. Intended, when circumstances permit, to determine solubility of synthesized compounds in water alone and in water containing salts commonly present in boiler water, to devise practicable methods of preventing formation of scales.—*W. P. R.*

The Advantages of Organic Colloidal Feedwater Treatment. HOWARD C. GOETZ, JR. Marine News. **27:** 5:41 ('40). Action of org. colloids in water treatment, unlike that of inorg. compds., is phys. rather than chem., and depends on adsorption, absorption and electrophys. polarization. Colloids remove scale-forming impurities from boiler water by coating or sheathing them; this prevents interlocking of crystals to form scale, and ppts. coated particles as sludge, which can be removed easily by blowdown. At same time colloids convert any existing scale to sludge that can be washed off metal with water. Since true colloids do not become dehydrated in contact with hot metal, completely heat-conductive film forms on plate and tubes, which hinders corrosion. In addn., colloids that are good absorbents prevent O and other gases from causing corrosion above water line. Treatment with org.

colloid permits higher concns. of solids in boiler water without foaming, and inhibits formation of foam blanket.—*C. A.*

Miniature Sulfur Burner Treats Feedwater at Necco. G. A. JOHNS. Power. **85:** 1: 57 (Jan. '41). 2 to 3 oz. sulfur per hr. converted into SO_2 by electrically heated burner. SO_2 dissolved in NaOH soln. and added to feed tank at rate of 2 g.p.m. for oxygen removal. $MnSO_3$ (1 p.p.m.) added as catalyst to increase rate of oxidation. 20 p.p.m. Na_2SO_3 in blowdown. Savings of $12.55 per 10^6 gal. on sulfate and sulfite at plant.—*T. E. Larson.*

Water Treatment at South Omaha Steam-Electric Station. R. R. BRIGGS. Combustion. **12:** 8: 27 (Feb. '41). Detailed operating experience indicated with Zeo-Karb hydrogen-sodium process for treatment of Missouri R. water for boiler feed. Effluent of 5–6 p.p.m. hardness, controlled alkalinity and appreciable reduction in dissolved solids obtained. Cost comparable with other proved methods of water treatment. Prior to aeration effluent from Zeo-Karb hydrogen-sodium combination corrosive to unprotected steel and cast iron.—*T. E. Larson.*

Effect of Lubricating Oil in Boilers and Methods for Control. G. E. DURHAM *et al.* Am. Ry. Eng. Assn., Bul. 414 ('40) p. 101a. Condensed steam exhausted from steam cylinders usually contains lubricating oils in varying amt. which may prove detrimental in further boiler use depending upon alkalinity, dissolved solids and degree of floc in boiler water. Even slight oily deposit on boiler heating surfaces produces insulating effect which reduces boiler efficiency and discontinuous oil coating may cause pitting. Treatment of feed water with suitable alkalies and coagulants may be considered effective means for correcting boiler troubles caused by oil.—*R. C. Bardwell.*

Cracks in Boilers With Special Reference to Caustic Embrittlement. W. O. ANDREWS. J. So. African Inst. Engrs. **38:** 94 ('39). Careful exam. of powerhouse boilers after explosion indicated that it was caused by cracks around rivet holes. Methods of inspection for prevention of explosions by caustic embrittlement are presented. Boiler drums are examined intact by removing rivets, cleaning and etching rivet holes and then examining them with magnifying glass and throat lamp to observe hair cracks. Short theory of caustic embrittlement up to modern concepts given.—*C. A.*

Steam-Boiler Damage Through Overheating the Materials of Construction. ERICH SCHULZ. Z. Ver. Deut. Ing. (Ger.) **85:** 177 ('41). Causes of failure of high pressure steam boilers discussed (German and American examples used). Overheating shown by appearance of internal coating of Fe_3O_4, by production of H, loss in phosphate content and alky. of boiler water as well as by excessive tube temps. (350° and above). Damage can be combated by (1) giving larger inclinations to tubes when boilers built; (2) decreasing or redistributing heat load; (3) treatment of boiler water to prevent displacement of Fe_3O_4 coating by decreasing salt content and keeping O content below 0.05 mg. per liter; and (4) increasing water circulation or fraction of water in steam-water mixture.—*C. A.*

Boiler Embrittlement Protection. C. W. RICE. Combustion. **12:** 7: 37 (Jan. '41). Present knowledge and prevailing practices in embrittlement protection reviewed. Explanations given for apparently conflicting experiences. Some salts including sodium sulfate and sodium silicate may accelerate or prevent embrittlement under different circumstances. Real cause for embrittlement lies in old type of boiler construction. Externally calked and combination externally and internally calked boilers should be eliminated. Where not possible, embrittlement properties of water in use should be determined and necessary corrections made if waters objectionable. 452 boiler plants operating at and above 400 lb. pressure built from '26 to date were 100% free from

embrittlement, except two cases due to faulty construction.—*T. E. Larson.*

Cause of and Remedy for Pitting and Corrosion of Locomotive Tubes and Sheets, With Special Reference to Status of Embrittlement Investigation. R. E. COUGHLAN *et al.* Am. Ry. Eng. Assn., Bul. 114 ('40) p. 96. Embrittlement detectors being applied to locomotives to determine action of concentrated boiler waters on stressed specimens of boiler steel while locomotive in actual service. Organic materials of sulfite waste liquor or tannin type tend to prevent intercrystalline corrosion of stressed steel by concentrated caustic solutions, but good construction and absence of leaks considered more important.—*R. C. Bardwell.*

Portland Acid—Cleans Boiler. D. L. BROWN, W. E. BRIGGS AND C. E. CORYEA. Power. **84:** 68 (Feb. '40). Large boiler cleaned with 1% muriatic acid inhibited with 1 lb. dry powdered Hibitite per 115 lb. acid in 9 hr., including 2 hr. post-treatment with .66% soda ash. —*T. E. Larson.*

Determination by the Evaporation Method of Small Amounts of Dissolved Solids in Water Such as Condensed Steam From Boilers. R. C. ULMER. Proc. A.S.T.M. **39:** 1221 ('39). Results obtained from investigation indicate that accurate determinations of steam purity can be obtained by evaporation method in 5 to 7 days with only a few minutes daily supervision. If more than 0.5 p.p.m. solids present, a smaller sample may be evaporated. Conductance and evaporation methods did not agree if ammonia was present. No constant calibration of conductance to evaporation method could be obtained. —*T. E. Larson.*

Mean Temperature Difference in Design. R. A. BOWMAN, A. C. MUELLER AND W. M. NAGLE. Trans. A. S. M. E. **62:** 4 (May '40). In heat-transfer apparatus, rate of heat flow from hot to cold fluid is proportional to temp. difference between two. For design purposes, it is necessary to be able to determine mean difference in temp. from inlet and exit temps. Numerous investigators have contributed analyses of temp. difference from exchangers with neither counter nor co-current flow. Paper co-ordinates results of previous studies on same basis, to give as complete picture as possible of all various arrangements of surface and flow. Shell-and-tube exchangers with any number of passes on shell side and tube side are covered as are crossflow exchangers with different pass arrangements and with mixed and unmixed flow. Special cases of trombone coolers, pot coolers, and batch processes, not previously published, are also treated in detail.—*Homer Rupard.*

Progress of Higher Pressures in the Industrial Plant. W. F. RYAN, Mech. Engr. **62:** 6 (June '40). "High pressure" a relative term, defined as not less than 500 lb. per sq.in. at prime-mover throttle. Under this definition, first high-pressure industrial power plant went into operation in '27, although another mfr. had installed 1250-lb. per sq.in. boiler for purely process work in '26. No high-pressure industrial plants reported in '28, and not more than 12 in operation at end of '33. Later development more rapid, but published records and other sources of information disclose only 85 plants, in which throttle pressure is 500 lb. per sq.in. higher, now operating in U. S., supplying power and steam to industries. No. includes 6 installations owned and operated by public utilities. Data on which survey is based drawn from these 85 plants, and while no claim made for completeness, believed that practically all major installations included. Plants have combined power-generating capac. of 1,166,875 kw., total steam-generating capac. of 30,785,300 lb. per hr., and represent probable investment of at least $125,000,000. No. of additional plants now under construction and expected that by end of '40 will be nearly 100 plants in operation with combined capac. of approx. 1,350,000 kw. Totals do not include plants, at least 40, where high-pressure boilers are installed to supply steam for process use only, for testing equipment, or for future power generation; nor do they include plants

in which boilers are designed for 500 to 600 lb. per sq.in., but which actually supply steam to prime movers at 425 to 475 lb. per sq.in. Foregoing figures include River Rouge power plant of Ford Motor Co., which contains one 15,000-kw. back-pressure turbine generator supplying steam to mfg. plant, and three 110,000-kw. high-pressure condensing units which differ in no way from typical central-station machines. In subsequent analyses, these 3 condensing units are excluded from totals in order to prevent distortion of aves. On this basis, combined capac. of 85 plants is 836,875 kw., of which 284,000 kw. operated by public utilities and 552,875 kw. by mfg. concerns. Industries have not hesitated to use highest pressures available for power generation, but have been somewhat indifferent to advantages of high pressure for process use. In general, temps. used have been lower than conditions might justify. Development of high-pressure reciprocating engine for power generation has been negligible but turbines have reached high peak of efficiency and adaptability to process requirements. General use of treated feed water requires boiler design with more heating surface than currently used in central-station service. Improved technique in feed-water treatment outstanding development in field, but water still major problem in operation of high-pressure industrial plants. Efficiencies and availability factors are high in well-designed plants. Ability to generate power with heat consumption of less than 5,000 B.t.u. per kw. hr. with plant cost—over cost of low-pressure steam plant—of little more than $100 per net kw. is proof of economy of such plants when load factor, synchronism of power and steam demands, and other factors are favorable. Absence of reserve or relay capac. in typical industrial plant should not be overlooked in making comparisons with earlier practice or with use of purchased power.—*Homer Rupard.*